DOCUMENT RESUME

ED 327 660 CE 056 670

AUTHOR	Buck, Sue; And Others
TITLE	Exploring Aeronautics and Space Technology. Teacher Edition.
INSTITUTION	Mid-America Vocational Curriculum Consortium, Stillwater, Okla.
PUB DATE	91
NOTE	435p.
AVAILABLE FROM	Mid-America Vocational Curriculum Consortium, Inc., 1500 West Seventh Avenue, Stillwater, OK 74074 (order no. 900101: $26.00).
PUB TYPE	Guides - Classroom Use - Guides (For Teachers) (052)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Aerospace Education; *Aerospace Technology; Air Transportation; Behavioral Objectives; Career Education; *Communications Satellites; Course Descriptions; Curriculum Guides; Learning Activities; Postsecondary Education; Secondary Education; Space Exploration; Space Sciences; Tests; Units of Study
IDENTIFIERS	Technology Education

ABSTRACT

This curriculum guide contains six units of instruction for an introduction to the technology systems in the National Aeronautics and Space Administration (NASA). Designed to be used either as a stand-alone publication or to be infused into the instruction and activities of an existing technology education program, this publication describes the interrelationship of the various technology systems in NASA. Introductory materials include a tools, materials, and equipment list; a list of 20 references; an instructional/task analysis that correlates related information with job training; and information on resources for teachers. Each instructional unit includes some or all of the following basic components: objective sheet; suggested activities for the teacher; teacher supplements; transparency masters; information sheet; assignment sheets; assignment sheet answers; lab activity sheets; written test; and test answers. Units are designed for use in more than one lesson or class period. Unit topics include introduction to the careers in the aviation and space industry; satellite communication systems; composite materials in airframe manufacturing; space-station construction techniques; space-shuttle propulsion systems; and aerostatics and aerodynamics. (YLB)

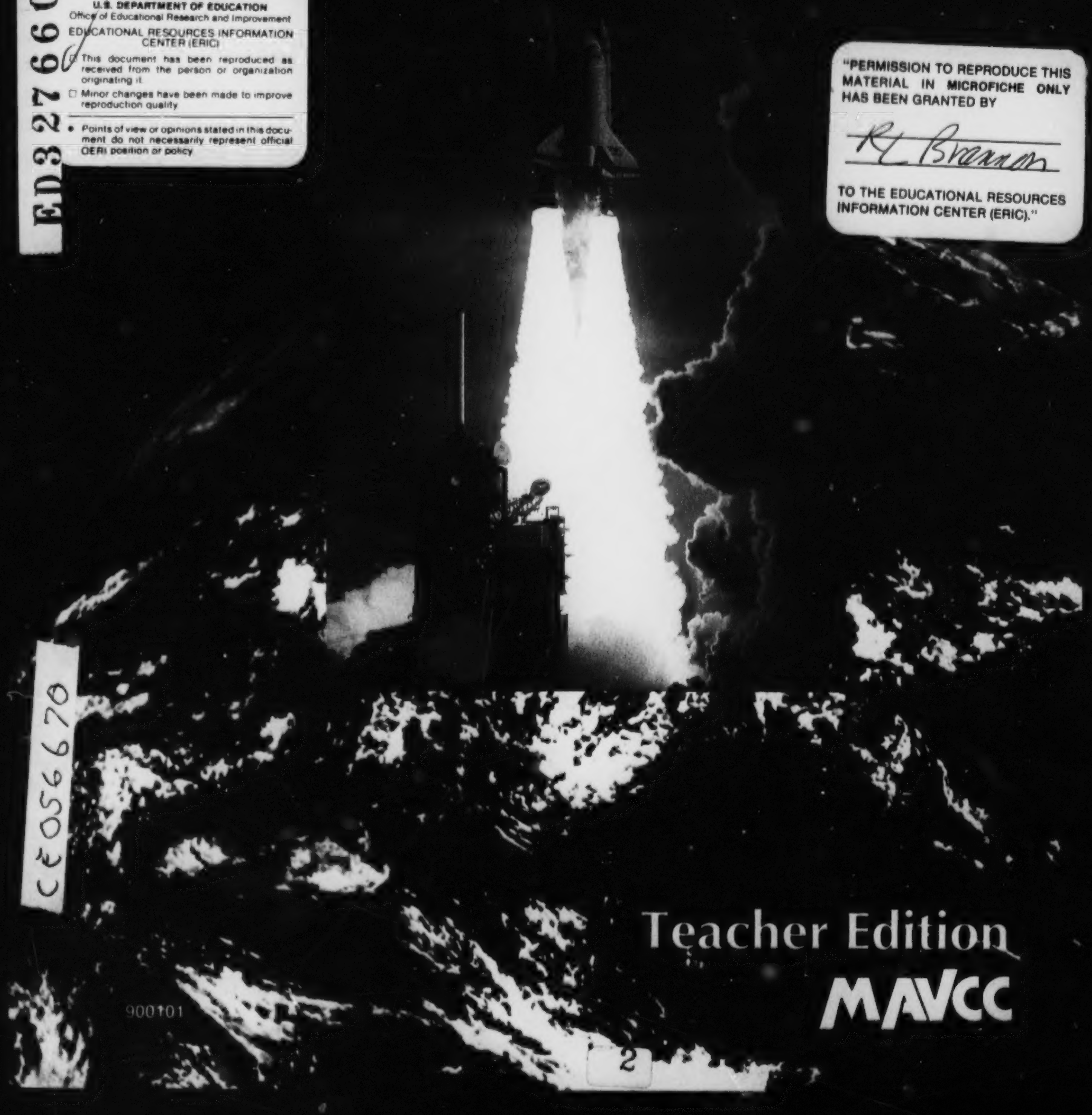
****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

EXPLORING AERONAUTICS AND SPACE TECHNOLOGY

ED327660

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY
RL Brannon
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."



CE056670

Teacher Edition

MAVCC

900101

Exploring Aeronautics and Space Technology

Written by

Sue Buck, Curriculum Specialist
Mid-America Vocational Curriculum Consortium, Inc.

Kevin Allen, Aerospace Education Specialist
Aviation and Space Education Department
Oklahoma State University

Eric Davis, Aerospace Education Specialist
Aviation and Space Education Department
Oklahoma State University

Project Coordinated by

Sue Buck, Curriculum Specialist
Mid-America Vocational Curriculum Consortium, Inc.

Project Developed by

The Mid-America Vocational Curriculum Consortium, Inc.

Board of Directors

Sylvia Clark, Texas, Chairman
Donna Brookhart, Colorado, Vice-Chairman
Janet Huss, Iowa, Parliamentarian
Jean McEntire, Arkansas
Carol Fagan, Kansas
David Poston, Louisiana
Harley Schlichting, Missouri
Ann Masters, Nebraska
Ann Benson, Oklahoma
Larry Nelson, South Dakota

Jim Steward, Executive Director

91-007669

900101

©1991 by the Mid-America Vocational Curriculum Consortium, Inc.

All rights reserved. No part of this book may be reproduced in any form or by any means without written permission from the publisher.

Printed in the United States of America by the Oklahoma Department of Vocational-Technical Education, Stillwater, OK 74074-4364.

Mid-America Vocational Curriculum Consortium, Inc.
1500 West Seventh
Stillwater, OK 74074-4364

Exploring Aeronautics and Space Technology

Table of Contents

Unit I: Introduction to the Careers in the Aviation and Space Industry . . . 1
Unit II: Satellite Communication Systems . . . 177
Unit III: Composite Materials in Airframe Manufacturing . . . 227
Unit IV: Space-Station Construction Techniques . . . 271
Unit V: Space-Shuttle Propulsion Systems . . . 343
Unit VI: Aerostatics and Aerodynamics . . . 423

Foreword

Exploring Aeronautics and Space Technology was developed as a cooperative effort of the Mid-America Vocational Curriculum Consortium (MAVCC) and the Aerospace Education Services Program of the National Aeronautics and Space Administration's (NASA's) Educational Affairs Division, Washington, D.C. The publication provides an introduction to the technology systems in NASA and describes the interrelationship of the various technology systems. *Exploring Aeronautics and Space Technology* has been designed to be used either as a stand-alone publication or to be infused into the instruction and activities of the existing MAVCC technology-education series. Developed to support technology-education programs, this series of publications allows students to explore the technology systems of communication, construction, manufacturing, and energy, power, and transportation.

Every effort has been made to make this publication basic, readable, and by all means, usable. Three vital parts of instruction have been intentionally omitted from the publication: motivation, localization, and personalization. These areas are left to the individual instructors and students. Only then will this publication become a vital part of the teaching/learning process.

Kenneth Wiggins
Program Director
NASA Aerospace Education
Services Program
Oklahoma State University

Sylvia Clark, Chairman
Board of Directors
Mid-America Vocational
Curriculum Consortium

Jim Steward
Executive Director
Mid-America Vocational
Curriculum Consortium

Acknowledgments

Appreciation is extended to those individuals who contributed their time and talent to the development of *Exploring Aeronautics and Space Technology*.

The contents of this publication were planned and reviewed by the following members of the Mid-America Vocational Curriculum Consortium committee:

Kenneth Wiggins
Head, Aviation and Space
Education Department
Oklahoma State University
Stillwater, Oklahoma

Nelson Ehrlich
Associate Director
Aerospace Education Services
Program
Oklahoma State University
Stillwater, Oklahoma

Greg Vogt
Aerospace Education Specialist
Aviation and Space
Education Department
Oklahoma State University
Stillwater, Oklahoma

Norman Poff
Aeronautics Specialist
Aviation and Space
Education Department
Oklahoma State University
Stillwater, Oklahoma

Malcolm Phelps
Aerospace Education Specialist
Aviation and Space
Education Department
Oklahoma State University
Stillwater, Oklahoma

Gordon Young
Industrial Technology Instructor
Overland High School
Aurora, Colorado

Roger Stacy
State Supervisor
Industrial Arts/Technology Education
Oklahoma Department of Vocational
and Technical Education
Stillwater, Oklahoma

Harold Holley
Assistant State Supervisor
Industrial Arts/Technology Education
Oklahoma Department of Vocational
and Technical Education
Stillwater, Oklahoma

Don Dale
Superintendent, Perkins/Tryon Schools
Perkins, Oklahoma

Myron Bender
Chairman, Industrial Technology
Department
University of North Dakota
Grand Forks, North Dakota

Marion Smith
Consultant
Stillwater, Oklahoma

Thanks are extended to Willie Tannahill for artwork and to the employees of the Graphics Division of the Oklahoma Department of Vocational and Technical Education for artwork, paste-up, phototypesetting, and printing of this text.

Special thanks are extended to Becky Allen, Science Instructor, Ripley High School, Ripley, Oklahoma, and Tim Allen, Science Instructor, Stillwater Jr. High, Stillwater, Oklahoma, who were members of the original development team.

Use of This Publication

Instructional units

Exploring Aeronautics and Space Technology contains six units of instruction. Each instructional unit includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, teacher supplements, transparency masters, information sheet, assignment sheets, assignment sheet answers, lab activity sheets, written test, and answers to written test.

All of the unit components "zero in" on measurable and observable learning outcomes. Instructors are encouraged to supplement, personalize, localize, and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the instructor will help him or her determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials, including print and nonprint media and equipment and supplies, that must be ordered.
- Resource people who must be contacted.

Objective sheet (white pages)

Each unit of instruction is based on the performance needed for successful completion of the unit. Performance objectives are stated in two forms: unit objectives, stating the subject matter to be covered in a unit of instruction, and specific objectives, stating the student performance necessary to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Instructors should prepare for each unit by deciding how each objective can best be taught.

Instructors should feel free to modify, delete, or add objectives in order to meet the needs of the students and community. When objectives are added, the instructor should remember to supply the needed information, assignment and/or lab-activity sheets, and criterion test items.

Suggested activities (pink pages)

This component is included only in the instructor material. The suggested-activities pages assist instructors during the preparation stage of the teaching/learning process by providing suggestions for delivery during the instructional process. The instructor should read the suggested activities before teaching the units to allow time to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the instructor will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the instructor to supplement her or his knowledge of the subject area or to help students with particular interests or occupational objectives in the area covered.

Teacher supplements (white pages)

This component is included only in the instructor material. Teacher supplements are optional materials for the instructor to use. They have three purposes: to provide the instructor with higher-level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the instructor may not have background or with information that is not readily available in other books.

Transparency masters (white pages)

Transparencies are graphic materials used to direct the students' attention to the topic of discussion. They may present new information, or they may reinforce information presented in the information sheet or in the assignment sheets. They appear only in the instructor material.

Information sheet (green pages)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Instructors will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and instructors to add notes that supplement, localize, personalize, or provide motivation for the teaching of each objective.

Student supplements (white pages)

Student supplements are included in the student material. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment or lab-activity sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information in the completion of assignment-sheet or lab-activity-sheet objectives will be evaluated when completing those particular assignments.

Assignment sheets (tan pages)

Assignment sheets provide students with information and exercises or problems that develop the knowledge that is a necessary prerequisite to skill development.

Lab activity sheets (blue pages)

The lab-activity sheets provide a list of equipment and materials and a procedure outline needed for practicing a psychomotor skill. The instructor should discuss the equipment and materials used—emphasizing the specific equipment and materials available in the classroom and/or laboratory—and provide the students with demonstrations of the lab activity prior to having students practice.

Lab activities are an important segment of each unit; they give direction to the skill being taught and allow both the student and instructor to check student progress toward the accomplishment of the skill.

Written test (yellow pages)

This component provides criterion-referenced evaluation of every information-sheet objective listed in the unit of instruction. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

The acceptable response on a unit test, 85 percent in most units, may be raised or lowered to fit the topic or students' ability levels. The percentage applies to the overall score, not to each individual test item. The final unit grade should be obtained by compiling the lab-activity evaluations, assignment-sheet scores, and the written-test score.

Assignment and written test answers (pink pages)

Assignment-sheet answers and written-test answers are designed to assist the instructor in evaluation of student performances. They are included only in the instructor material.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some instructors ask students to furnish a three-ring binder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some instructors store the materials by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student materials contain objective sheets, information sheets, student supplements, the assignment sheets, lab activity sheets, and written tests. All tests are collated at the back of the student material and should be removed and stored until needed. Students should be allowed to take their materials home at the end of the course.

Teaching methods

It is a challenge to keep students motivated. Instructors should supplement the objectives by providing the "why," personal experiences, and current information. Prepare for each unit by deciding how each objective can best be taught. Allow students to become involved in preparing and planning their teaching/learning experiences.

Exploring Aeronautics and Space Technology

Tools, Materials, and Equipment List

Unit II

- Hard-seal modulated helium-neon laser and manufacturer's instruction manual
- Microphone supplied with laser
- 3-inch focal-length lenses supplied with laser
- Light-wave receiver
- Movable, adjustable stand and strapping mechanism for laser
- Movable stand and strapping mechanism for receiver
- Mirror
- Ring stand

Unit III

- Desk or other flat work surface
- Large, flat weights
- Balsa-wood sheet material
- Posterboard
- Paper
- Glues (white glue and wood glue)
- Solid wood
- Carbon paper
- Narrow-bladed handsaw such as a coping saw or keyhole saw
- Scissors
- X-acto knife
- Eye protection
- Sandpaper

- File
- Workbench
- C-clamps
- 20- to 30-pound-test fishing line
- Drill and drill bit
- Scale
- Weight hanger and weights

Unit IV

- Ramagon Toys, Inc.: two "Very Big Builder Sets" and one "Special Long-Rod Package" per space station to be built

Unit V

- Long party balloons
- Tape measures
- Nylon-filament fishing line
- Plastic straws
- Styrofoam coffee cups
- Masking tape
- Scissors
- Solid-propellant model rocket kits

Unit VI

- Butcher paper
- Posterboard
- Tissuepaper
- Permanent felt-tip markers
- Glue sticks
- All-wire coat hangers
- Pliers

- String
- Small hand-held hairdryer
- Propane-burning camp stove
- Standard stove pipe
- Desk or other flat work surface
- Newspaper
- Scissors
- X-acto knife
- Ruler
- Glue
- T-pins or glass-bead pins
- Whitewing balsa/fiber model glider kits

Exploring Aeronautics and Space Technology

References

Balistreri, Jerry, ed. *Laser Technology*. Salt Lake City, Utah: Utah State Board of Vocational Education, July, 1985.

Career Search Occupational Abstracts. Stillwater, Oklahoma: Oklahoma State Department of Vocational and Technical Education, Career Search Division, n.d.

Gottlieb, Herbert H., ed. *101 Ways to Use a Laser Plus Some More Just for Fun*. Bellmawr, New Jersey: Metrologic Instruments, Inc., 1987.

Haggerty, James. National Aeronautics and Space Administration, Office of Commercial Programs, Technology Utilization Division. *Spinoff 1985* and *Spinoff 1986*. Washington, D.C.: U.S. Government Printing Office.

Haynes, Robert. *NASA Facts: Sentinels in the Sky: Weather Satellites*. National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration (NOAA), n.d.

Hexcel Products, Inc. *HEXCEL Honeycomb*. Dublin, California: HEXCEL, March, 1973.

Laser—Technology Education Learning Activity Package. Stillwater, Oklahoma: Oklahoma Department of Vocational and Technical Education, Technology Education Division, n.d.

Lynch, Richard L., and Edwin L. Herr. *Career Core Competencies: Getting the Job*. New York: Gregg Division, McGraw-Hill Book Company, 1977.

NASA Facts: Life Aboard the Space Shuttle. Kennedy Space Center, Florida: National Aeronautics and Space Administration, John F. Kennedy Space Center, 1985.

National Aeronautics and Space Administration. *NASA Educational Briefs*, "Liquid-Propellant Rockets," 1982. Washington, D.C. 20546. Government Printing Office Number 1982-361-570-414/3257.

National Aeronautics and Space Administration. *NASA Educational Briefs*, "Solid Propellant Rockets." Washington, D.C. 20546. Government Printing Office number 883-556.

National Aeronautics and Space Administration. *NASA FactSheet: Propulsion Trivia*, MSFC-Form 2914-12 (Rev. March 1980). George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812.

National Aeronautics and Space Administration. *NASA, The First 25 Years 1958-1983: A Resource for Teachers*. Washington, D.C.: Government Printing Office, 1983.

Poff, Norman O. *Of Wings and Things*. Oklahoma State University, Stillwater, Oklahoma: NASA Educational Services, 1987.

Space Shuttle News Reference. National Aeronautics and Space Administration, n.d.

Space Station Freedom Media Handbook. Washington, D.C.: Office of Space Station, NASA Headquarters, April 1989.

Station Break. Washington, D.C.: NASA Technical and Administrative Services Corporation (TADCORPS).

Talay, Theodore A. *Introduction to the Aerodynamics of Flight*. Washington, D.C.: National Aeronautics and Space Administration, Scientific and Technical Information Office, 1975.

Taylor, John W. R., ed. *The Lore of Flight*. Crescent Books, distributed by Crown Publishers, Inc., New York, copyright 1986.

Vogt, Gregory, *Rockets* (preliminary draft). National Aeronautics and Space Administration, Aerospace Education Services, n.d.

Exploring Aeronautics and Space Technology

Instructional/Task Analysis

Unit I: Introduction to the Careers in the Aviation and Space Industry

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
1. Terms associated with the careers in the aviation and space industry	
2. Occupational areas in the aviation and space industry	
3. Career-interest areas in the aviation and space industry	
4. Steps in career decision making	
5. Description of the interrelationship of the occupational areas in the aviation and space industry	
	6. Gather personal information
	7. Gather general job information and identify occupational and career-interest areas of choice
	8. Gather specific job information
	9. Make career decision
	10. Develop plan of action to meet career goal
	11. Explore the interrelationship of the occupations in the aviation and space industry

Unit II: Satellite Communication Systems

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
1. Definitions of the terms *communication* and *interference*	

Unit II (cont.)

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
2. Stages of a basic communication system	
3. Forms of interference that can occur at various stages in a basic communication system	
4. Importance of feedback in a basic communication system	
5. Parts of the process in a basic communication system	
6. Parts of the process in a satellite communication system	
7. Parts of the process in a helium-neon laser communication system	
	8. Practice constructing an interference-free message
	9. Use a laser to simulate satellite communication

Unit III: Composite Materials in Airframe Manufacturing

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
1. Terms associated with airframe manufacturing	
2. Components of the manufacturing system model	
3. Definition of the term *manufacturing technology*	
4. NASA's role in aeronautics manufacturing technology	
5. Definition of the term *composite material*	

Unit III (cont.)

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
6. Types of bonding processes used in manufacturing composite materials	
7. Major types of composite materials used in airframe manufacturing	
	8. Calculate strength-to-weight ratios
	9. Fabricate composite materials
	10. Construct and test wing spars

Unit IV: Space-Station Construction Techniques

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
1. Terms associated with space-station construction	
2. Components of the construction system model	
3. Definition of the term *construction technology*	
4. Objectives of space-station design	
5. Major space-station structural elements	
6. Techniques to be used in space-station construction	
	7. Investigate scientific uses of Space Station Freedom
	8. Plan productive and managerial processes for constructing a model of Space Station Freedom
	9. Construct a model integrated truss assembly
	10. Construct a complete model of the major structural elements of Space Station Freedom

Unit V: Space-Shuttle Propulsion Systems

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
1. Terms associated with propulsion systems	
2. Types of rocket propulsion systems	
3. Parts of a solid-propellant rocket engine	
4. Parts of a liquid-propellant rocket engine	
5. Principle of rocket propulsion	
6. Major units of the Space Shuttle's propulsion system	
7. Major components of the Space Shuttle's main engines	
8. Major components of the Space Shuttle's external tank	
9. Major components of the Space Shuttle's solid-rocket boosters	
	10. Compare the propulsion systems of solid- and liquid-propellant rockets
	11. Simulate a multi-stage rocket launch
	12. Construct a solid-propellant model rocket

Unit VI: Aerostatics and Aerodynamics

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
1. Terms associated with aerostatics and aerodynamics	
2. The Buoyancy Principle	
3. Bernoulli's Principle	

Unit VI (cont.)

Related Information: What the worker should know (cognitive)	Job Training: What the worker should be able to do (psychomotor)
4. Basic forces acting on an aerodyne in flight	
5. Basic parts of a glider	
6. Components of the cross-sectional shape of an aircraft's wing	
7. Definition of *dihedral angle*	
	8. Build an aerostatic vehicle
	9. Build an aerodynamic vehicle

Resources for Teachers

Teacher Resource Center Network

For more than 25 years, the NASA Educational Affairs Division has provided educational programs and materials for teachers and students from the elementary to the university level. One of the newer programs is the NASA Teacher Resource Center Network, a dissemination mechanism to provide educators with NASA educational materials.

Teachers need immediate access to the information that is generated by NASA programs, technologies, and discoveries, so they can bring that excitement into their classrooms. NASA educational materials are related to art, mathematics, energy, physics, careers, spaceflight, aeronautics, technology utilization, physical science, and social science. They are a valuable supplement to textbook instruction.

To help disseminate these materials to elementary and secondary educators, the NASA Educational Affairs Division has established the NASA Teacher Resource Center Network. The network comprises Teacher Resource Centers, Regional Teacher Resource Centers, and the Central Operation of Resources for Educators.

Teacher Resource Centers (TRCs). Located at the nine NASA research centers, TRCs have a variety of NASA-related educational materials in several formats: videotapes, slides, audiotapes, publications, lesson plans, and activities. NASA educational materials are available to be copied at the TRCs. Contact the nearest TRC for further information. (See the following list of TRCs.)

Regional Teacher Resource Centers (RTRCs). As a way to expand the reach for the NASA Teacher Resource Center Network, NASA forms partnerships with universities and museums to serve as RTRCs, with plans to have the RTRC in each state. There teachers preview NASA materials, make copies of the materials, or obtain audiovisual materials from the CORE.

Central Operation of Resources for Educators (CORE). Designed for the national and international distribution of aerospace educational materials to enhance the NASA Teacher Resource Center Network, CORE provides educators with another source for NASA educational audiovisual materials. CORE will process teacher requests by mail for a minimal fee. On school letterhead, educators can write for a catalogue and order form. Send requests to:

NASA CORE
Lorain County Joint Vocational School
15181 Route 58 South
Oberlin, OH 44074.

List of Teacher Resource Centers

If you live in	*Contact this Teacher Resource Center*
Alaska Arizona California Hawaii Idaho Montana Nevada Oregon Utah Washington Wyoming	NASA Ames Research Center Attn: Teacher Resource Center Mail Stop 204-7 Moffett Field, CA 94035
	NASA Jet Propulsion Laboratory Attn: Teacher Resource Center JPL Educational Outreach Mail Stop CS-530 Pasadena, CA 91109
Florida Georgia Puerto Rico Virgin Islands	NASA John F. Kennedy Space Center Attn: Educator Resource Library Mail Stop ERL Kennedy Space Center, FL 32899
Kentucky North Carolina South Carolina Virginia West Virginia	NASA Langley Research Center Attn: Teacher Resource Center Mail Stop 146 Hampton, VA 23665-5225
	University of North Carolina at Charlotte Attn: Lorraine Penninger NASA Teacher Resource Center J. Murrey Atkins Library Charlotte, NC 28223
Colorado Kansas Nebraska New Mexico North Dakota Oklahoma South Dakota Texas	NASA Lyndon B. Johnson Space Center Attn: Teacher Resource Center Mail Stop AP-4 Houston, TX 77058
	U.S. Space Foundation Attn: NASA Teacher Resource Center (1525 Vapor Trail) (Colorado Springs, CO 80916) P.O. Box 1838 Colorado Springs, CO 80901
Mississippi	NASA National Space Technology Laboratories Attn: Teacher Resource Center Building 1200 NSTL, MS 39529
Connecticut Delaware District of Columbia Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	NASA Goddard Space Flight Center Attn: Teacher Resource Laboratory Mail Stop 130.3 Greenbelt, MD 20771
	NASA Industrial Applications Center Attn: Christa McAuliffe Teacher Resource Institute 823 William Pitt Union University of Pittsburgh Pittsburgh, PA 15260
	Champlain College Attn: NASA Teacher Technology Resource Center 174 South Willard Street Burlington, VT 05402-0670
Connecticut Delaware District of Columbia Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont (cont.)	The City College Attn: NASA Teacher Resource Center NAC 5/208 New York, NY 10031
	National Air and Space Museum Attn: Education Resource Center P-700 Office of Education Washington, DC 20560
Illinois Indiana Michigan Minnesota Ohio Wisconsin	NASA Lewis Resource Center Attn: Teacher Resource Center Mail Stop 8-1 Cleveland, OH 44135
	Parks College of St. Louis University Attn: NASA Teacher Resource Center Cahokia, IL 62206
	Museum of Science and Industry Attn: NASA Teacher Resource Center 57th Street at Lakeshore Drive Chicago, IL 60637
	University of Evansville Attn: NASA Teacher Resource Center School of Education 1800 Lincoln Avenue Evansville, IN 47714
	Children's Museum Attn: NASA Teacher Resource Center P.O. Box 3000 Indianapolis, IN 46206
	Northern Michigan University Attn: NASA Teacher Resource Center Olson Library Media Center Marquette, MI 49855
	Central Michigan University Attn: NASA Teacher Resource Center Mount Pleasant, MI 48859
	St. Cloud State University Attn: NASA Teacher Resource Center Center for Information Media St. Cloud, MN 56301
	Mankato State University Attn: NASA Teacher Resource Center Curriculum and Instruction Box 52 Mankato, MN 56001
	University of Wisconsin at LaCrosse Attn: NASA Teacher Resource Center Morris Hall, Room 200 LaCrosse, WI 54601

If you live in	*Contact this Teacher Resource Center*
Illinois Indiana Michigan Minnesota Ohio Wisconsin (cont.)	Discovery World Attn: NASA Teacher Resource Center 818 West Wisconsin Center Milwaukee, WI 53233 Oakland University Attn: NASA Teacher Resource Center O'Dowd Hall, Room 115 Rochester, MI 48063

If you live in	*Contact this Teacher Resource Center*
Alabama Arkansas Iowa Louisiana Missouri Tennessee	Alabama Space and Rocket Center Attn: NASA Teacher Resource Center Huntsville, AL 35807 Bossier Parish Community College Attn: NASA Teacher Resource Center 2719 Airline Drive Bossier City, LA 71111

Other NASA Educational Services

The National Aeronautics and Space Administration offers educators a wide range of educational services including speakers, publications, audiovisual materials, software, advanced educational technology, curriculum assistance, electronic communications, in-school satellite programs, student programs, and training opportunities. Additional information and contact addresses follow in the sections below.

Aerospace Education Services Program (AESP). The AESP provides qualified Aerospace Education Specialists for student and teacher programs. These specialists are available for teacher workshops, conferences, curriculum consultations, interactive laser-disk demonstrations, assembly programs, classroom presentations, civic and professional group programs, and television and radio appearances.

Request the services of an AESP specialist for your school by contacting the Education Office at the regional NASA center that serves your state. (See the following list of NASA Regional Centers.)

Spacelink. Spacelink is an electronic information service operated by the Marshall Space Flight Center. It provides NASA news and educational resources including software programs that can be accessed by anyone with a computer and modem.

Interested educators should write to the Marshall Space Flight Center Education Office for the Spacelink phone number and other details.

NEWMAST. NASA, in conjunction with the National Science Teacher's Association and the National Council of Teachers of Mathematics, sponsors annual NASA Education Workshops for Math and Science Teachers (NEWMAST) at several regional NASA Centers. Teachers accepted for these two-week workshops receive educational materials, observe current scientific research and development activities, and are briefed in aeronautics, space sciences, and astronomy, while interacting with scientists and engineers in their research laboratories.

Nominations for teachers to attend NEWMAST must be received by April 15 to be eligible for the following summer's NEWMAST workshop. Request nomination packets from the address below.

NEWMAST
NSTA
1742 Connecticut Avenue, NW
Washington, DC 20009

Teacher workshops. Each summer, several thousand teachers attend aerospace workshops at NASA Regional Centers or at colleges and universities. AESP specialists and NASA scientists often play a major role in workshop sessions. These workshops provide aeronautical and space-science information supplemented with hands-on activities and curriculum resources. College credit may be provided by the sponsoring institution.

Information concerning regional aerospace workshops in which NASA is participating can be obtained by contacting your NASA Regional Center Education Office.

Space Science Student Involvement Program (SSIP). The SSIP is an annual competition for students in grades 7 through 12 sponsored by the National Science Teachers Association and NASA. The competition fosters student research in four categories: space station, zero gravity, wind-tunnel research, and journalism. Student winners receive opportunities to visit NASA facilities and interact with scientists and engineers.

Additional information about the competition is available from the following address:

National Science Teachers Association
1742 Connecticut Avenue, NW
Washington, DC 20009

Urban Community Enrichment Program (UCEP). UCEP is an opportunity for urban school districts to participate in aerospace-education activities. NASA aerospace-education specialists visit district schools for an intensive three-day period to promote awareness of aerospace careers, motivate students, and provide supplemental material and technical assistance for teachers.

To request UCEP for your urban school district, contact:

NASA UCEP Manager
NASA Educational Affairs Division (Code XEE)
NASA Headquarters
Washington, DC 20546

Summer High School Apprenticeship Research Program (SHARP). SHARP is designed to attract under-represented minorities and women to aerospace careers. Selected high school students, living within commuting distances from participating NASA centers, become summer apprentices to scientists and engineers. SHARP students carry out assignments under the supervision of a mentor, prepare reports, and participate in a variety of enrichment activities.

To learn more about SHARP, contact:

NASA SHARP Manager
NASA Educational Affairs Division (Code XEE)
NASA Headquarters
Washington, DC 20546
(202) 453-8397

Lunar Sample Education Project. Representative samples of rock and soil from the Moon are available for loan to teachers to use with their students. The samples are encased in a clear-plastic disk for use with a stereo microscope. Printed and audiovisual materials accompany the samples to provide a complete package of classroom activities.

To qualify for a lunar-sample loan, educators must attend a certification workshop. Please contact your regional NASA Education Office for information about future certification workshops.

Science fairs. NASA annually participates in the International Science and Engineering Fair (ISEF) and affiliated fairs. Winning students and their teachers from the ISEF receive trips to NASA regional centers for tours and enrichment activities. NASA also provides Certificates of Achievement for affiliated fairs.

For more information about NASA science and engineering fair participation, contact:

NASA Science Fair Manager
NASA Educational Affairs Division (Code XEE)
NASA Headquarters
Washington, DC 20546
(202) 453-8759

NASA Regional Center Education Offices

If you live in	*Write to the Education Office at*
Alaska Arizona California Hawaii Idaho Montana Nevada Oregon Utah Washington Wyoming	NASA Ames Research Center Moffett Field, CA 94035
Connecticut Delaware District of Columbia Maine Maryland Massachusetts New Hampshire New Jersey New York Pennsylvania Rhode Island Vermont	NASA Goddard Space Flight Center Greenbelt, MD 20771
Colorado Kansas Nebraska New Mexico North Dakota Oklahoma South Dakota Texas	NASA Lyndon B. Johnson Space Center Houston, TX 77058
Florida Georgia Puerto Rico Virgin Islands	NASA John F. Kennedy Space Center Kennedy Space Center, FL 32899
Kentucky North Carolina South Carolina Virginia West Virginia	NASA Langley Research Center Langley Station Hampton, VA 23665-5225
Illinois Indiana Michigan Minnesota Ohio Wisconsin	NASA Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135
Alabama Arkansas Iowa Louisiana Missouri Tennessee	NASA George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812
Mississippi	NASA National Space Technology Laboratories Building 1200 NSTL, MS 39529

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

UNIT OBJECTIVE

After completing this unit, the student should be able to identify occupational and career-interest areas in the aviation and space industry, develop a plan of action for meeting a career goal within the industry, and discuss the interrelationship of the occupational areas in the industry. The student will demonstrate these competencies by completing the assignment sheets and the written test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with careers in the aviation and space industry to their correct definitions.
2. Match occupational areas in the aviation and space industry to their correct definitions.
3. Match career-interest areas in the aviation and space industry to their correct definitions.
4. List steps in career decision making.
5. Describe the interrelationship of the occupational areas in the aviation and space industry.
6. Gather personal information. (Assignment Sheet 1)
7. Gather general job information and identify occupational and career-interest areas of choice. (Assignment Sheet 2)
8. Gather specific job information. (Assignment Sheet 3)
9. Make career decision. (Assignment Sheet 4)
10. Develop plan of action to meet career goal. (Assignment Sheet 5)
11. Explore the interrelationship of the occupations in the aviation and space industry. (Assignment Sheet 6)

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

SUGGESTED ACTIVITIES

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review teaching suggestions given in the "Delivery and Application" section and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan presentation to take advantage of student learning styles and to accommodate special-needs students.
- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the "Suggested Resources" section.
- Prepare classroom and lab. Put up posters, charts, and signs; display articles related to the objectives of this unit. Carefully review Assignment Sheets 1 through 5 and display all reference materials required to complete these exercises.

Delivery and Application

Unit introduction

- Provide students with objective sheet. Discuss unit and specific objectives.
- Show the videotape "it's A New World."
- Provide students with information sheet. Discuss information sheet.

Objective 1 Match terms associated with careers in the aviation and space industry to their correct definitions.

- Point out the differences in the definitions of the terms *job*, *occupational area*, and *career*. In common usage, people seldom differentiate much between the meanings of these terms; however, in this unit these terms are to be used in clearly different contexts. Point out and expand on the example given under the definition of each term to help students learn the precise meanings as they are used in this unit: a *job* is a specific activity such as a computer operator performs; a computer operator works in the *occupational area* of communication, where all the jobs involve changing information into messages that can be transmitted. And within that occupational area, a computer operator may pursue a *career* path that finally leads him or her to the ultimate career goal of computer systems analyst.

SUGGESTED ACTIVITIES

- Also take time to help students clearly differentiate between the terms *occupational area* and *career-interest area*. Besides the definitions listed in the objective, another main point to be stressed is that career-interest areas can be found in all the occupational areas. For example, the career-interest area of scientists—as defined in Objective 3—can be found in all the occupational areas of the aviation and space industry defined in Objective 2: communication, construction, manufacturing, and energy, power, and transportation.

- Treat the four terms *interest*, *aptitude*, *skill*, and *value* as a group, as they all relate to the first step in the career decision-making process presented in Objective 4 and further explored in Assignment Sheet 1. Lead a class discussion in which students are asked to read the definitions and then work in groups to come up with an example to show how these terms relate. An example of this is given below:

  My primary **interest** is technical writing in the aerospace field. I discovered my **aptitude** for writing when I noted my grades on composition were always good in my high school English classes and when I found that I especially enjoyed doing composition assignments in the aerospace components of my Technology Education class. I took a class in computer keyboarding and word processing to help me learn two **skills** that will make my compositions more professional looking and easier to compose. I think I **value** technical writing over other jobs because it allows me to use my creativity while writing about the aerospace field I like so much.

Objective 2 Match occupational areas in the aviation and space industry to their correct definitions.

- Conduct a class discussion in which you have students recall the definitions of these four occupational areas, which they have studied in the basic technology education books in this series. Write each subject heading on the chalkboard and then complete definitions at the end of the discussion.

- Point out to students that in this unit they will be learning to use the general definitions of communication; construction; manufacturing; and energy, power, and transportation in a more specific sense—as they directly relate to the aerospace industry. In this unit, they will learn about the jobs in the various aerospace areas and explore the jobs in one occupational area of their choice.

SUGGESTED ACTIVITIES

Objective 3 Match career-interest areas in the aviation and space industry to their correct definitions.

- Have students recall the definitions of *interest* and *career-interest area* they reviewed in Objective 1 of the information sheet. Relate these terms to the definitions given for career-interest areas in this objective. Again, stress that within each occupational area there are many career-interest areas; therefore, each student will have many career options within the occupational area they will choose to explore in this unit.

Objective 4 List steps in career decision making.

- Discuss with students the fact that many of the careers in the aerospace industry have their counterparts in other industries, and although we will be discussing the careers in the aerospace industry specifically, this career exploration can also transfer to more general areas if the student finds that he or she has little interest in the aerospace industry. An example of this is this objective. Although students will be using the seven steps in the career decision-making process to explore specific careers within the aerospace industry, learning these seven steps in this context will also provide them with a framework for exploring careers in other industries. Relate this framework to the flow chart presented in Figure 1 in the information sheet and discuss how it can be used in all career exploration.

  Explain that students will be carefully guided through each of these seven steps of career decision making in Assignment Sheets 1 through 5.

- Read with students Step 1 in the career decision-making process: Gather personal information by defining your interests, aptitudes, skills, and values. Discuss with students that both formal and informal interest inventories can be used as tools to help them define their own interests, aptitudes, skills, and values. Formal interest inventories are standard tests administered and evaluated by trained personnel such as the school counselor. These formal tests have no right or wrong answers. They just have questions especially designed to determine students' interests *if* they answer the questions as honestly as possible.

  Informal interest inventories are similar to formal inventories as they also ask questions that have no right or wrong answers and they too can be used as a tool for determining students' interest if they answer the questions as honestly as possible. The difference between the two types of inventories is that the student administers and evaluates an informal self-inventory. Encourage students to utilize both types of inventories if possible in determining their personal interests, aptitudes, skills, and values.

SUGGESTED ACTIVITIES

Relate to students that in Assignment Sheet 1, "Gather Personal Information," they will be using an informal self-inventory to define their interests, aptitudes, skills, and values. Again, stress that there are no right or wrong answers to this assignment sheet and, therefore, there is no "score" line on the assignment sheet. Evaluations will be based on the student's seriousness of effort and completeness rather than on correctness.

Read with students the introduction to Assignment Sheet 1 and carefully discuss the information presented. Then read and discuss the directions to the various sections of the exercise (self-inventory) included in the assignment. Have students complete Assignment Sheet 1.

Read with students Step 2 in the career decision-making process: Gather general job information. Relate to students that during this step they will do some general research into the occupational and career-interest areas in the aerospace industry so that they can sample the types of jobs available in each area.

Read with students Step 3 in the career decision-making process: Identify occupational area of choice and a career-interest area of choice. Explain that during this step students will identify an occupational and career-interest area that best meets the interests, aptitudes, skills, and values they identified in Assignment Sheet 1.

Hand out and discuss Assignment Sheet 2, "Gather General Job Information and Identify Occupational and Career-Interest Areas of Choice." Explain that the introduction to the assignment sheet is divided into two informational sections: (1) occupational areas in the aerospace industry and (2) career-interest areas in the aerospace industry. These informational sections will provide students with the general information they will need for a "sample" of the different occupations in the aerospace industry. Emphasize that students should take notes on the occupational and career-interest areas that seem to match their interests, aptitudes, skills, and values identified in Assignment Sheet 1. Then, in the exercise associated with this assignment sheet, they will be asked to first rank and then identify both an occupational and career-interest area of choice. Therefore, they will have completed Step 2 and Step 3 in the career decision-making process.

Read with students and then discuss the directions to the various sections of the exercise included in the assignment. Have students complete Assignment Sheet 2.

SUGGESTED ACTIVITIES

- Read with students Step 4 in the career decision-making process: Gather specific job information to compare jobs within occupational area of choice and career-interest area of choice. Explain that at this step the students will be locating and compiling specific job information for the jobs within the occupational and interest areas they chose in Assignment Sheet 2.

Display the basic reference materials students will need to locate specific job information in the areas they have chosen: *Occupational Outlook Handbook*, *Dictionary of Occupational Titles*, and *Guide for Occupational Exploration*.

Discuss with students the information in Teacher Supplement 1, "Education and Training Levels." This information is basic to their understanding the educational levels discussed in the resources they will be using.

Hand out Assignment Sheet 3, "Gather Specific Job Information," and read the introduction to the assignment. Emphasize the type of job information that can be obtained from the three basic references listed above and discussed in the introduction. Demonstrate the method used to retrieve information from each of these three sources.

Arrange a field trip to the library/media center, where the librarian should show students where complete sets of the three basic references are located and also discuss additional job information that can be found in that particular library, such as career publications, books, and magazines.

Have a representative of a computerized guidance program, such as the Career Search program mentioned in the introduction to the assignment, come to the classroom and demonstrate the computer program and show samples of the types of information resulting from the program. Discuss the information included in the "Career Search Booklet" provided in Student Supplement 1 of this unit.

Discuss with students other methods of obtaining job information, such as conducting personal interviews, watching audiovisual presentations, and contacting apprenticeship programs or state employment agencies.

Read with students the section of the introduction called "What you want to know" and explain how Student Supplement 2, "Job-Information Report Form," asks students to provide the type of information requested in this section of the introduction.

Read and discuss with students the directions to the exercise included in the assignment. Have students complete Assignment Sheet 3.

SUGGESTED ACTIVITIES

- Read with students Step 5 in the career decision-making process: Make a career decision (define career goal). Then hand out copies of Assignment Sheet 4, "Make Career Decision," and Student Supplement 3, "Job-Comparison Worksheet." Read with students the introduction to the assignment sheet and discuss the information presented. Then read and discuss the directions to the exercise and the use of Student Supplement 3. Have students complete Assignment Sheet 4.

- Read with students Step 6 in the career decision-making process: Develop a plan of action. Then hand out Assignment Sheet 5, "Develop Plan of Action to Meet Career Goal" and Student Supplements 4 through 8.

  Read with students the introduction to the assignment sheet, pointing out that creating a career plan of action merely involves developing short-term and long-term objectives and then listing these objectives in chronological order. By following the steps in the exercise in Assignment Sheet 5, the students will be carefully guided through the objective-setting process.

  Read with students the directions to the exercise and discuss the completion of the student supplements. Show students copies of Teacher Supplement 2, "Sample Plan of Action," in your discussion of the directions for completing this assignment.

  Have students complete Assignment Sheet 5.

- Read with students Step 7 in the career-decision-making process. Remind students that they should review and revise their plan of action as needed in the future to reflect their changing interests and skills, but that they should not change the plan of action for foolish reasons. They should always think about what they are doing and perhaps go through this decision-making process each time they believe their skills and interests have changed. Again, refer to Figure 1 in the information sheet when making this point.

Objective 5 Describe the interrelationship of the occupational areas in the aviation and space industry.

- Discuss with students the fact that, as they do in all industries, the personnel in all the occupational areas in the air and space industry must work together to complete their missions. Then go over the basic explanations in the information sheet. Hold a class discussion to be sure students understand this interrelationship.

SUGGESTED ACTIVITIES

- Have all students turn in the "Job-Information Report Forms" they completed in Assignment Sheet 3. Then you compile (or have students compile) all their forms into one large file divided by occupational-area headings.

  Have students review the report forms, and then conduct a class discussion on the activities performed in the various jobs.

- Hand out copies of Assignment Sheet 6, "Explore the Interrelationship of the Occupations in the Aviation and Space Industry," and Student Supplement 9, *NASA Facts*, "Life Aboard the Space Shuttle." Read with students the introduction to the assignment sheet and discuss the directions to the exercise. Have students complete Assignment Sheet 6.

Evaluation

- Give written test.
- Compile written-test and assignment-sheet scores.
- Reteach and retest as required.
- Complete appropriate section of competency profiles.

Suggested Resources

Resources used in developing unit

Print media

- Kelly, Joan, and Ruth Volz-Patton. *Career Skills*. Encino, California: Glencoe Publishing Company, 1987, 256 pages including glossary and subject index.

  This well-designed and clearly written textbook is divided into two parts. Part one deals with career exploration and Part two with employment skills. The book is easy to read and has lots of colorful pictures and cartoons—making it interesting to look at. And it is full of ideas that will help seventh- to ninth-grade students begin their career exploration and learn the skills that will help them find that first job.

- Lynch, Richard L., and Edwin L. Herr. *Career Core Competencies: Getting the Job*. New York: Gregg Division, McGraw-Hill Book Company, 1977, 136 pages.

  This soft-back book combines informational articles and workbook-type activities into a format called a *text-workbook*. It contains 14 chapters divided into the following four unit headings: Deciding on a Job That Fits You, Getting Your Records Together, Preparing to Go Job Hunting, and Going to Get the Job.

SUGGESTED ACTIVITIES

Resources used as student references

(NOTE: The materials listed below were used as resources in preparing Student Supplement 1: "Career Search Booklet.")

- *Career Search Occupational Abstracts.* Stillwater, Oklahoma: Oklahoma State Department of Vocational and Technical Education, Career Search Division, n.d.

  Oklahoma teachers may order a computerized version of the Career Search program for either Apple, IBM, or IBM-compatible computers by contacting the

  Career Search Division
  Oklahoma Department of Vocational
  and Technical Education
  1500 West Seventh Avenue
  Stillwater, OK 74074-4364

  Phone: 1-800-522-5810.

  Teachers in other states may order a similar computerized program from

  COIN Educational Products
  3361 Executive Parkway, Suite 302
  Toledo, OH 43606

  Phone: 1-800-274-8515.

(NOTE: The pamphlet listed below was used as the resource in preparing Student Supplement 9.)

- *NASA Facts: Life Aboard the Space Shuttle.* Kennedy Space Center, Florida: National Aeronautics and Space Administration, John F. Kennedy Space Center, 1985.

Resources to be used to supplement unit materials

Media

- *it's A New World.* ACE Distribution Service, c/o Kansas Careers, College of Education, Kansas State University, Manhattan, Kansas 66506; phone (913) 532-6540.

  Videotape and curriculum guide. The videotape is a product of the ACE Consortium and was developed by the South Carolina Employment Security Commission in cooperation with the NASA Aerospace Education Services Project, Oklahoma State University.

SUGGESTED ACTIVITIES

The curriculum guide was developed under the guidance of the Oklahoma SOICC and Oklahoma State Department of Vocational and Technical Education.

By viewing the video and going through the 13 activities in the curriculum guide, students will consider the importance of science and math education in their future, link science and math education to careers, and learn about six sample occupations that use science and math.

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

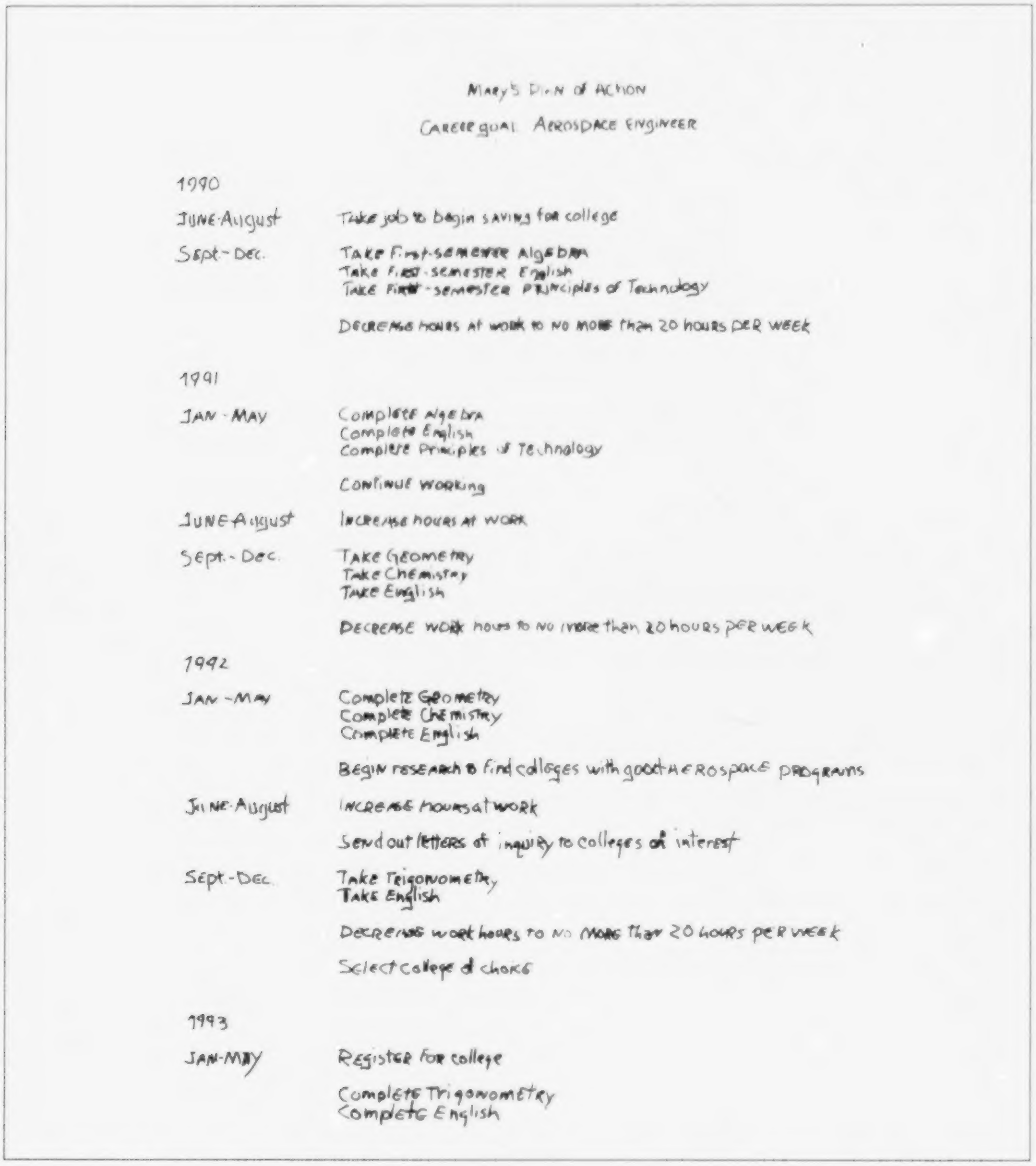
TEACHER SUPPLEMENT 1—EDUCATION AND TRAINING LEVELS

Type	Description	Length of training	Transfer credit
OJT	On-the-job training is specific training by the employer. This includes military service.	Usually less than 6 months	
HS diploma	This entry-level training is offered at comprehensive high schools.	1 to 3 years	Some credits may be transferable to postsecondary programs.
Certificate	This training centers on specific skills of a particular occupation. It may be offered through private vocational schools or community colleges.	3 months to 2 years	
Apprenticeship	This formal training program involves work experience and classroom instruction.	2 to 5 years	Only credits earned in a college may be transferable.
Associate degree	This training in specific vocations is offered at community colleges.	2 years	Some credits may be transferable to 4-year programs.
Bachelor's degree	This formal training program leads to a degree from a college or university.	4 years	Credits may be transferable between colleges and universities.
Master's degree	This advanced degree is required for entry into certain careers.	1 to 2 years beyond a Bachelor's	Credits may be transferable between colleges and universities.
Doctorate	This training is for such professions as physician, dentist, lawyer, pastor, scientist, and college teacher.	3 to 5 years beyond a Bachelor's	Credits may be transferable from one program to another.

Reprinted with permission of Oregon Careers 1989, from the Oregon Occupational Information Coordinating Committee, Salem, Oregon.

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

TEACHER SUPPLEMENT 2—SAMPLE PLAN OF ACTION



Mary's Plan of Action

Career goal Aerospace Engineer

1990	
June-August	Take job to begin saving for college
Sept-Dec.	Take first-semester Algebra Take first-semester English Take first-semester Principles of Technology
	Decrease hours at work to no more than 20 hours per week
1991	
Jan-May	Complete Algebra Complete English Complete Principles of Technology
	Continue working
June-August	Increase hours at work
Sept.-Dec.	Take Geometry Take Chemistry Take English
	Decrease work hours to no more than 20 hours per week
1992	
Jan-May	Complete Geometry Complete Chemistry Complete English
	Begin research to find colleges with good aerospace programs
June-August	Increase hours at work
	Send out letters of inquiry to colleges of interest
Sept-Dec.	Take Trigonometry Take English
	Decrease work hours to no more than 20 hours per week
	Select college of choice
1993	
Jan-May	Register for college
	Complete Trigonometry Complete English

TEACHER SUPPLEMENT 2

Graduate

June-August Find part-time job for college

Sept-Dec Complete first-semester college

1994

Complete second-semester college

Find summer internship in aerospace industry and secure employment for following summers
Complete third-semester college

1995

Complete fourth-semester college

Complete summer internship in aerospace industry

Complete fifth-semester college

1996

Complete sixth-semester college

Complete summer internship in aerospace industry and do research on companies that may provide future employmen

Complete seventh-semester college

Prepare resume and begin career search

1997

Complete eighth-semester college

Send out resumes and complete career search

Graduate

Obtain employment as an aerospace engineer

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

INFORMATION SHEET

1. **Terms and definitions associated with careers in the aviation and space industry**

   a. **Aviation and space industry** (aerospace industry)—Industry involved with the design, construction, manufacture, or flight of an aircraft, satellite, or space vehicle

   b. **Job**—Planned or responsible activity a person performs with expectation of return for efforts

   EXAMPLE: Computer operator

   c. **Occupational area**—Group of jobs similar according to the nature of the work being performed

   EXAMPLE: Communication

   d. **Career**—Path person follows within occupational area

   EXAMPLE: Computer operator to computer programmer to computer systems analyst

   e. **Career-interest area**—Group of jobs similar according to interests; work activity occurring in all occupational areas

   EXAMPLE: Scientists

   f. **Interest**—Thing, subject, or activity in life that you like to do or that makes you happy

   g. **Aptitude**—Talent or potential for being able to do something

   h. **Skill**—Activity you have been trained to do and have practiced doing

   i. **Value**—Personal judgment concerning the importance or worth of a thing or quality

2. **Occupational areas in the aviation and space industry and their definitions**

   a. **Communication**—Jobs involved with changing information into messages that can be transmitted

   b. **Construction**—Jobs involved with using manufactured goods and materials to build structures on site

   c. **Manufacturing**—Jobs involved with using raw materials and processes to produce products that are used elsewhere

INFORMATION SHEET

d. **Energy, power, and transportation**—Jobs involved with converting energy into mechanical, fluid, and electrical power

3. **Career-interest areas in the aviation and space industry and their definitions**

a. **Scientists**—People whose job interests include studying how the universe operates, observing the natural world, creating hypotheses to explain their studies and observations, and then carrying out experiments to validate their hypotheses

EXAMPLES: **Physical scientists**: astronomer, chemist, geologist, meteorologist, physicist; **life scientists**: biological scientist, physician, psychologist, dietitian and nutritionist; **social scientists**: economist, sociologist; **mathematicians**: computer programmer, mathematician, computer systems analyst, statistician

b. **Engineers**—People whose job interests include applying physical and mathematical principles to solve specific real-world problems

EXAMPLES: Aerospace engineer, chemical engineer, civil engineer, biomedical engineer, electrical and electronics engineer, industrial engineer, mechanical engineer, nuclear engineer, petroleum engineer, metallurgical and materials engineer, architect

c. **Technicians**—People whose job interests include building, operating, and maintaining the complex equipment that bring engineers' designs to life

EXAMPLES: Engineering technician, aircraft mechanic, welder, metal/plastic machine operator

d. **Technical communicators**—People whose job interests include developing prose and artwork for books, magazines, newspapers, radio and television, brochures, and advertisements

EXAMPLES: Writer and editor, visual artist, educational administrator, public relations specialist, photographer and camera operator, radio operator, word processor

e. **Crew members**—People whose job interests include piloting air- and spacecraft and performing scientific or technical investigations or operating specialized equipment

EXAMPLES: Astronaut, pilot, mission specialist, payload specialist

4. **Steps in career decision making** (see Figure 1)

(NOTE: Making a career decision is the first step you should take to ensure that you reach the lifestyle you want for your future. Therefore, it is a very important decision. However, many people just take any job available at the time they go to work and they never find the career path that would give them the future they want. Such people often have never been taught the steps that would guide them through the process of making careful and logical career decisions. By learning and then practicing the following steps, you control the important process whereby you decide your future.)

INFORMATION SHEET

a. Gather personal information (define your interests, aptitudes, skills, and values)

(NOTE: During this first decision-making step, you should conduct a formal or informal self-inventory [1] to define your present interests, aptitudes, and skills and [2] to ask yourself important questions about your personal values. Where will you want to live? How much time will you want to devote to your job? How much travel will you want to do in your job? How much money will you need?)

b. Gather general job information

(NOTE: During the information-gathering step, you will locate general information about occupational areas and career-interest areas, and you will become aware of the types of jobs available in the various occupational and interest areas.)

c. Identify occupational area of choice and career-interest area of choice

(NOTE: During this step, you will identify an occupational area and a career-interest area within that occupational area in which the jobs seem to best meet your interests, aptitudes, and skills and also fulfill your values.)

d. Gather specific job information to compare jobs within occupational area of choice and career-interest area of choice

(NOTE: At this step, you will locate and compile specific job information for the jobs within the occupational and interest areas you have chosen. Specific job information will include duties, working conditions, work requirements, earnings and advancement opportunities, employment outlook, and required educational and training levels of the jobs.)

e. Make career decision (define career goal)

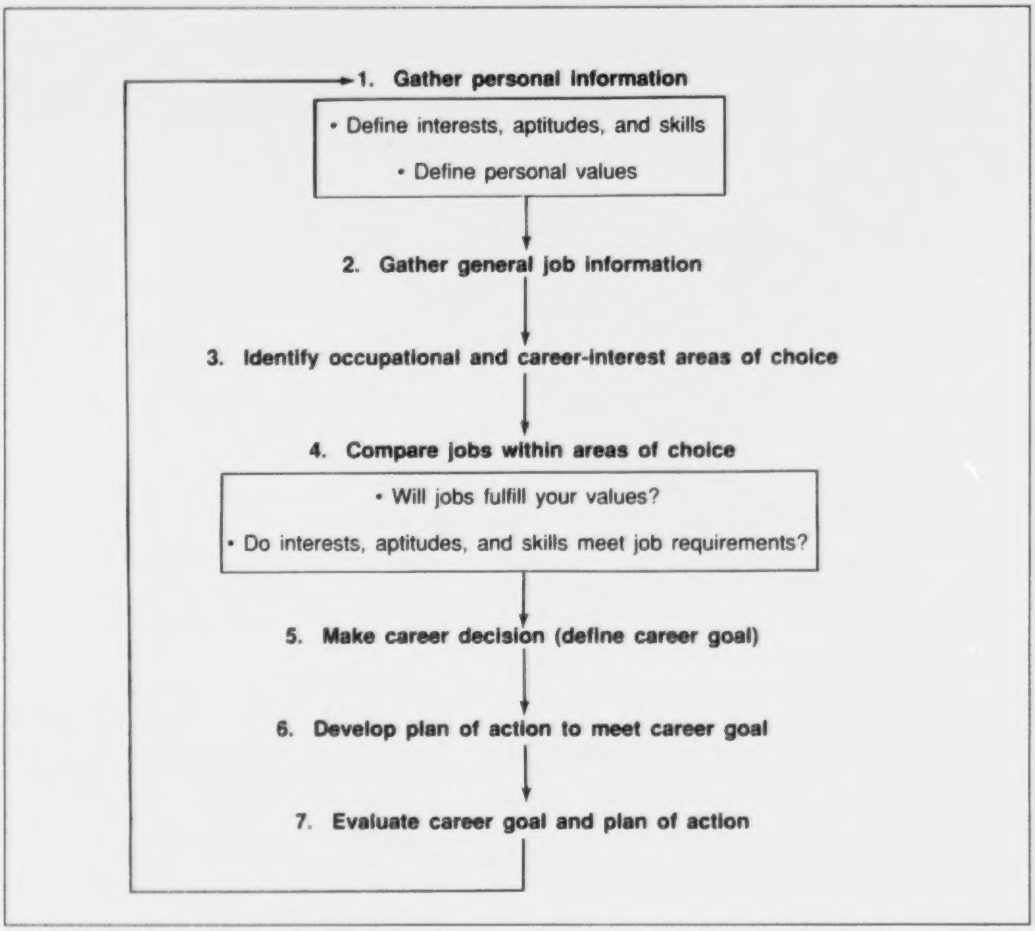
f. Develop plan of action to meet career goal

g. Evaluate career goal and plan of action

(NOTE: As you age your interests and skills may change and circumstances may require a change in your plan of action. Continue asking yourself questions to determine whether or not this career and plan of action are still appropriate. If you find they are not, begin the decision-making process again.)

INFORMATION SHEET

FIGURE 1

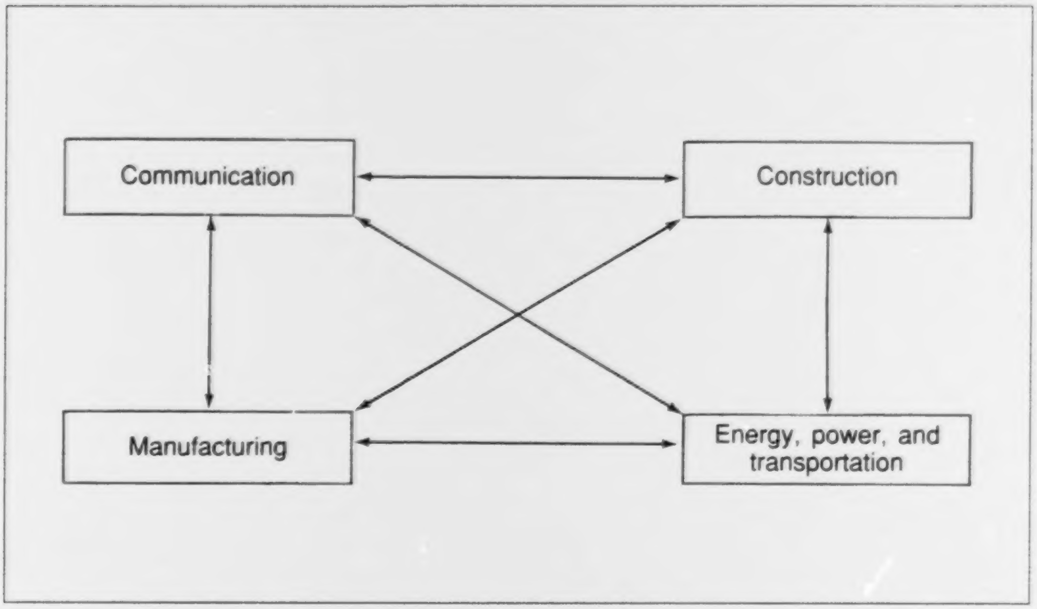

1. Gather personal information
• Define interests, aptitudes, and skills
• Define personal values
2. Gather general job information
3. Identify occupational and career-interest areas of choice
4. Compare jobs within areas of choice
• Will jobs fulfill your values?
• Do interests, aptitudes, and skills meet job requirements?
5. Make career decision (define career goal)
6. Develop plan of action to meet career goal
7. Evaluate career goal and plan of action

INFORMATION SHEET

5. **Interrelationship of the occupational areas in the aviation and space industry** (Figure 2)

(NOTE: Teamwork is an important part of the lives of all aviation and space industry personnel. Engineers, technicians, scientists, technical communicators, and crew members in all the occupational areas depend on the competence and expertise of each other to succeed in their missions.)

FIGURE 2



a. **Communication**—Provides the exchange of information required between occupational areas for the efficient operation of manufacturing plants, construction sites, and transportation systems

b. **Construction**—Builds structures to house manufacturing and communication enterprises; to produce, store, and transmit power; and to transport materials and products

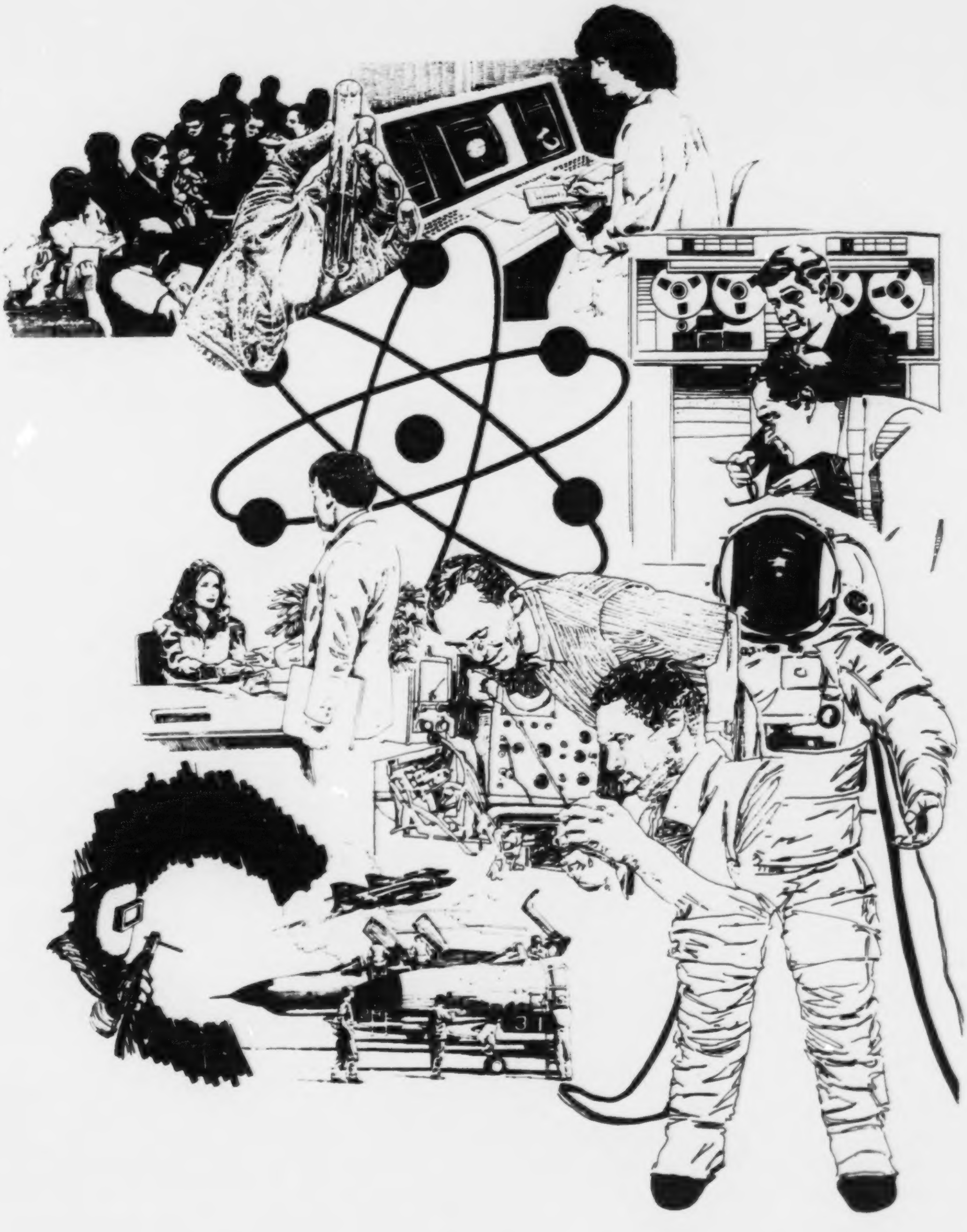
c. **Manufacturing**—Produces products and processes used in the other three occupational areas

EXAMPLES: Runways and railroads for transportation; dams to store water for producing electrical power; structures to house manufacturing and communication enterprises

d. **Energy, power, and transportation**—Produces, stores, and transmits power used in manufacturing, construction, and communication; moves materials and products used by manufacturing, construction, and communication

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 1—CAREER SEARCH BOOKLET



All career abstracts, except for "Astronaut," were developed by and reprinted with the permission of the Career Information Division of the Oklahoma State Department of Vocational and Technical Education.

GROUP 1: SCIENTISTS

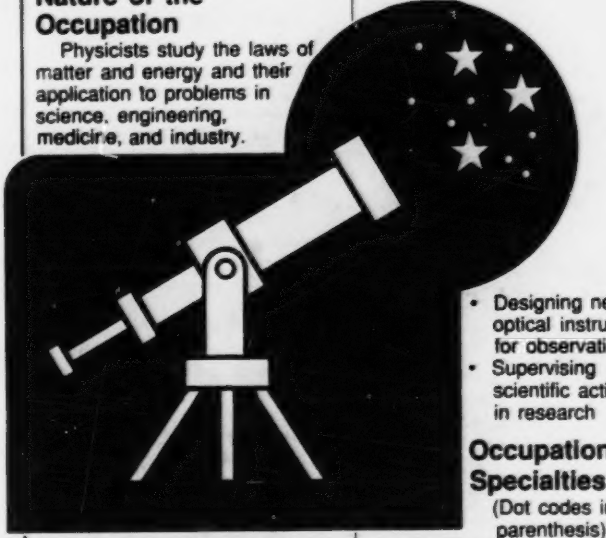
PART A: PHYSICAL SCIENTISTS

NORTH
82
65.
49.

PHYSICIST AND ASTRONOMER

Nature of the Occupation

Physicists study the laws of matter and energy and their application to problems in science, engineering, medicine, and industry.



Astronomers observe and interpret celestial phenomena. They are concerned with the origin, evaluation, composition, motion, relative position, and size of the solar system.

Duties may include but are not limited to the following:

- Devising procedures for conducting research and physical testing of materials
- Determining physical properties of materials
- Relating and interpreting research
- Describing observations and conclusions in mathematical terms
- Developing theories/laws based on observation and experiments
- Developing mathematical tables and charts for navigational and other purposes
- Designing new optical instruments for observation
- Supervising scientific activities in research

Occupation Specialties

(Dot codes in parenthesis)

Solid State Physicists (023.061-014) study the structure and properties of matter in solid state that result from the association of atoms and molecules.

Nuclear Physicists (023.061-014) study the nature and characteristics of atomic nuclei.

Astrophysicists (021.067-010) study temperature luminosity and chemical composition of celestial bodies.

Working Conditions

Physicists and astronomers may work alone or with other members of a research team. They usually work in clean, well-lighted laboratories, offices, and classrooms or in observatories.

Physicists and astronomers must take precautions against exposure to radiation, high voltage electrical equipment, and toxic materials.

Physicists and astronomers often work over 40 hours a week, and certain types of research projects may require travel. Travel costs may be paid by the employer.

Physicists and astronomers may join associations such as the American Institute of Physics and the American Astronomical Society. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Standard Laboratory Equipment
- Cameras & Televisions
- Vibrometers, Oscillographs & Spectrographs
- Computers
- Lasers
- Telescopes, Optical & Radio
- Spectrometers, Photometers & Radiometers
- Phase & Electron Microscopes
- Masers
- Super Conducting Magnets

Worker Requirements

You should like:

- Activities of scientific and technical nature
- Activities dealing with things and objects
- Activities which involve the use of machines and processes

You should be able to:

- Pay close attention to detail
- Perform a variety of duties which may change often
- Detect differences in the shape, size, and make up of things
- Rate information by using personal judgment and measurable standards
- Direct, control, and plan activities

OCCUPATION SPECIALTIES

DOT CODE:

021.067-010	Astronomer
021.067-010	Astrophysicist
023.061-014	Physicist, Solid State
023.061-014	Physicist, Nuclear
023.061-014	Physicist

SOC CODE: 1842, 1843

OKLAHOMA
CAREER
SEARCH

PHYSICIST AND ASTRONOMER

Physically you must:
- See well, either naturally or with correction
- Use your hands and fingers easily

Special Requirements:
More than half of all bachelor's degree recipients go on to graduate school. The best positions are available to those with a Ph.D. For a career in research or teaching at the university level a Ph.D. is generally required. With a bachelor's or master's degree a person may enter design and development work or teaching at the high school or two-year college level.

Opportunities for Experience:
Summer or part-time jobs may be available in observatories. Military service and membership in a science club also offer opportunities for experience.

Methods of Entry:
Methods of entering this occupation include direct application to employers and civil service offices and by consulting college placement offices, professional journals and newspaper want ads.

Earnings and Advancement

Earnings depend upon the employer, geographic location, and employee's educational level and experience.

Earnings:
Nationally, in 1987, physicists and astronomers in private industry graduating with a master's degree earned an average yearly salary of $31,200. Those graduating with a Ph.D. earned an average salary of $42,500. Experienced physicists and astronomers earned an average yearly salary of $33,000, with ranges of $28,000 to $45,000 annually.

Physicists and astronomers graduating with a bachelor's degree and employed by the Federal Government earned starting salaries ranging from $14,820 to $18,350 in 1987. Those graduating with a master's degree earned salaries between $18,350 and $22,450. Ph.D. graduates earned salaries ranging from $27,170 to $32,560. Experienced physicists and astronomers earned an average yearly salary of about $45,600 in 1987.

Fringe Benefits:
Depending on the employer, physicists and astronomers may receive paid vacations and holidays; life and health insurance; and a pension plan. These benefits are usually paid for, at least in part, by the employer.

Employment and Outlook

There were approximately 22,000 physicists and 3,000 astronomers employed nationally in 1987. Employment opportunities in physics are expected to be moderate through the year 2000 for persons with a doctorate in physics because employment is projected to grow slower than the average for all occupations over the period. As a result, the number of graduate degrees awarded annually in physics has been declining since 1970. Persons seeking jobs in astronomy are expected to continue to encounter competition for the small number of available openings that will occur through the year 2000.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Calculus
- Statistics
- Chemistry
- Electricity & Electronics
- Algebra
- Geometry
- Trigonometry
- Physics
- Astronomy

More Sources of Information

- American Institute of Physics
  335 East 45th Street
  New York, NY 10017

- American Physical Society
  335 East 45th Street
  New York, NY 10017

- American Astronomical Society
  Dr. Peter B. Boyce
  2000 Florida Ave., NW, #300
  Washington, DC 20009

- Society of Physics Students
  American Institution of Physics
  335 E. 45th Street
  New York, NY 10017

- College Placement Offices

CHEMIST

Nature of the Occupation

Chemists investigate the composition, structure, and properties of substances and the transformation they undergo for use in basic or applied research.

Duties may include but are not limited to the following:

- Devising new equipment and developing formulas, processes, techniques, and methods for solving technical problems
- Conducting research into the relationships between molecular, chemical and physical properties of substances and compounds
- Conferring with scientists and engineers
- Preparing and presenting findings
- Administering and managing programs in industrial production

Occupation Specialties

(Dot codes in parenthesis)

Analytical Chemists (022.061-010) analyze chemical compounds and mixtures to determine their composition. They also conduct research to develop or improve techniques, methods, procedures, and the application of instruments to chemical analysis.

Organic Chemists (022.061-010) conduct experiments on essentially carbon or silicon substances. They may also conduct research in agricultural products and foods.

Inorganic Chemists (022.061-010) conduct experiments on substances which are free or relatively free of carbon. They may also conduct research in relation to metals, ores, gases, heavy chemicals and products such as glass.

Physical Chemists (022.061-010) conduct research into the relationships between chemical and physical properties of organic and inorganic compounds.

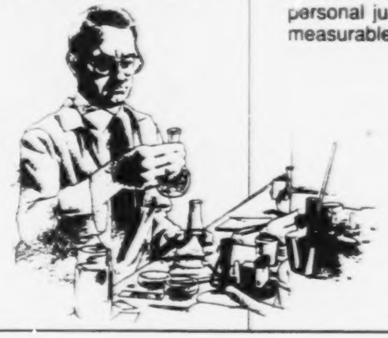
Working Conditions

Chemists often work alone although they may work with other scientists, engineers, and technicians at various stages of research or development. They may supervise chemical technicians and other workers in production operations.

Chemists usually work in modern, well-equipped and lighted laboratories or offices. Some chemists are exposed to health or safety hazards when handling certain chemicals, but there is little risk if proper procedures are used.

Chemists usually work 40 hours a week although overtime may be required. Work-related travel may also be necessary.

Chemists may join such organizations as the American Chemical Society, the Chemical Manufacturers Association, and the American Institute of Chemists. Member usually pay dues.



Tools, Equipment and Materials used may include:

- Microscopes
- Computers
- Chromatographs
- Spectroscopes
- Spectrophotometers
- Reports and Reference Materials

Worker Requirements

You should like:

- Activities of a scientific and technical nature
- Activities which require creative imagination
- Working with things and objects

You should be able to:

- Understand and use scientific theories and data
- Perform a variety of duties which may change often
- Work within precise limits or standards of accuracy
- Use logical step-by-step procedures to complete tasks
- Visualize drawings or pictures as solid objects
- Rate information using personal judgment or measurable standards

OCCUPATION SPECIALTIES

DOT CODE:

022.061-010	Chemist
022.061-010	Chemist, Analytical
022.061-010	Chemist, Organic
022.061-010	Chemist, Inorganic
022.061-010	Chemist, Physical

SOC CODE: 1845

OKLAHOMA
CAREER
SEARCH

CHEMIST

- Perform arithmetical operations quickly and accurately
- Direct, control, and plan activities
- Communicate well, bother orally and in writing

Physically you must:
- Use your arms, hands, and fingers well
- Possess eye and hand or finger coordination
- See well, either naturally or with correction, including color vision

Special Requirements:
While there are some job opportunities for chemists with a bachelor's degree, most employers prefer some graduate training. The best positions are open to applicants who have a master's degree or Ph.D. Teaching positions in colleges and universities usually require a Ph.D., as do research positions in industry.

Opportunities of Experience:
Summer or part-time work in chemical, industrial, or agricultural laboratories can provide helpful experience.

Methods of Entry:
Methods of entering this occupation include direct application to employers and civil service offices. Positions may also be located by consulting newspaper want ads, professional publications, and college placement offices.

Earnings and Advancement

Earnings depend upon the size and type of employer and employee's education, experience, and nature of responsibilities.

Earnings:
Beginning chemists with a bachelor's degree earned a starting salary averaging $23,400 in 1987. Chemists graduating with a master's degree average $28,000 annually. Chemists with a Ph.D. earned a beginning salary of approximately $36,400 in 1987. Experienced chemists received salaries ranging from $33,000 to $74,600, with the median salary being $41,500.

Chemists graduating with a bachelor's degree earned a starting salary of $16,500 with the Federal Government in 1987. Chemists having a Ph.D. earned salaries ranging from $27,172 to $32,567. The average salary for all chemists employed by the Federal Government was $38,600 a year.

Fringe Benefits:
Depending on the employer, chemists may receive paid vacations and holidays; life, accident, disability and hospitalization insurance; retirement plans; and sick pay. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Administrator
- Supervisor of Research
- Chemist

Chemists may advance through experience and by working on more complex assignments.

Employment and Outlook

There were approximately 105,000 chemists employed nationally in 1987. Employment of chemists is expected to grow more slowly than the average of all occupations through the year 2000. Most openings will occur in fields relating to pharmaceutical and biotechnology. Other openings will occur as a result of chemists transferring to other occupations.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Calculus
- Trigonometry
- Chemistry
- Algebra
- Geometry
- Biology
- Physics

More Sources of Information

- American Chemical Society
  1155 16th Street, NW
  Washington, DC 20036

- American Institute of Chemists
  7315 Wisconsin Avenue
  Bethesda, MD 20814

- Chemical Manufacturers Association
  2501 M Street, NW
  Washington, DC 20037

- Local, State, and Federal Civil Service Offices

- College Placement Offices

GEOLOGIST & GEOPHYSICIST

Nature of the Occupation

Geologists investigate the structure, composition, and history of the earth's crust and apply relevant knowledge to engineering problems and environmental impact.

Duties may include but are not limited to the following:

- Examining rocks, minerals, and fossil remains
- Determining and explaining the sequence of the earth's development
- Interpreting research data
- Recommending specific studies or actions
- Preparing reports and maps

Occupation Specialties

(Dot codes in parenthesis)

Petroleum Geologists (024.061-022) study the earth's surface and subsurface to locate gas and oil deposits and help develop extraction processes.

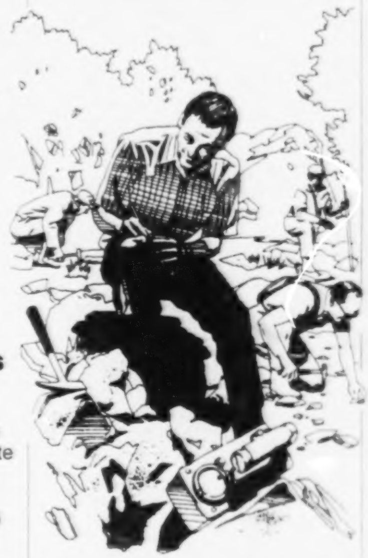
Mineralogists (024.061-038) examine, analyze, and classify minerals, gems, and precious stones and study their occurrence and chemistry.

Paleontologists (024.061-042) study the fossilized remains of plants and animals to determine the development of past life and history of the earth.

Hydrologists (024.061-034) study the distribution and development of waters in land areas and evaluate findings in reference to such problems as flood and drought, soil and water conservation, and inland irrigation.

Geological Oceanographers (024.061-018) study the ocean bottom.

Physical Oceanographers (024.061-030) study the physical aspects of oceans such as currents and their interaction with the atmosphere.



Seismologists (024.061-050) interpret data from seismographs and other instruments to locate earthquakes and earthquake faults.

Stratigraphers (024.061-054) study the distribution and arrangement of sedimentary rock layers by examining their contents.

Working Conditions

Geologists may work alone or with others. Geologists may work outdoors in all types of terrain and weather conditions, or in comfortable, well-lighted, and ventilated offices and laboratories.

Geologists working in offices and laboratories usually work 40 hours a week, and those working in the field usually work long and irregular hours.

Exploration geologists may receive assignments of varying length and destinations and may be required to travel to different parts of the United States or foreign countries. While on field trips, exploration geologists often travel to remote sites by helicopter or jeep and cover large areas by foot.

Geologists may join professional organizations such as the Geological Society of America and the American Association of Petroleum Geologists. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Compasses
- Seismographs
- Clinometers
- Core Drills
- Gravity Meters
- Hammers & Chisels
- Records
- Visible, Infrared & Side-Scanning Radar
- Transits
- Levels
- Microscopes
- Electron Microscopes
- Atomic Absorption Spectrophotometers
- X-ray Diffraction/Fluorescence Spectrometers
- Cameras

OCCUPATION SPECIALTIES

DOT CODE:

024.061-018	Geologist	024.061-018	Geological Oceanographer
024.061-022	Geologist, Petroleum	024.061-030	Physical Oceanographer
024.061-038	Mineralogist	024.061-050	Seismologist
024.061-042	Paleontologist	024.061-054	Stratigrapher
024.061-034	Hydrologist		

SOC CODE: 1847

OKLAHOMA CAREER SEARCH

GEOLOGIST & GEOPHYSICIST

Worker Requirements

You should like:
- Problem solving
- Scientific and technical work
- Activities of an abstract and creative nature
- Work involving things and objects
- Outdoor work

You should be able to:
- Apply scientific and mathematical theory to real problems
- Perform research
- Work accurately within set limits and standards
- Perceive and record differences in the size, shape, form, texture, and position of objects
- Work well with others
- Prepare written reports

Physically you must:
- See well, either naturally or with correction
- Be able to stoop, kneel, crouch, climb, and balance
- Be able to reach for, handle, and hold instruments
- Be able to lift and carry objects weighing up to 50 pounds

Opportunities for Experience:

Summer work with exploration companies and geological research projects may be available and provide experience.

Methods of Entry:

Methods of entering this occupation include direct application to employers and taking civil service exams. Positions may also be located by consulting professional associations and publications, college placement offices, and state employment offices.

Earnings and Advancement

Earnings depend upon the geologist's particular position, occupational specialty, amount of experience, and level of education.

Earnings:

Nationally, in 1987, geologists graduating with a bachelor's degree earned an average starting salary of $19,200; those with a master's degree started at an average of $22,458; and those with a Ph.D. earned $33,000. Geologists with a Ph.D. working in private industry with experience earned salaries averaging $44,270 annually.

Geologists working for the Federal Government in 1987 started at $14,822 to $18,358 with a bachelor's degree; $18,358 to $22,458 with a master's degree; and $27,172 to $32,567 with a Ph.D. In 1987, the average salary for geologists in the Federal Government was $37,500 and $40,900 for geophysicists.

Career Ladder for this Occupation may look like this:
- Self-employed Consultant
- Program Manager
- Project Leader
- Geologist

Employment and Outlook

There were approximately 52,400 geologists employed nationally in 1987. Employment of geologists is expected to grow more slowly than the average through the year 2000. Best prospects are available for those with knowledge and experience in geophysical oil and gas exploration techniques, but employment opportunities will remain low until oil prices increase enough to make exploration worthwhile.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Trigonometry
- Earth Science
- Geography
- English
- Geometry
- Chemistry
- Physical Science
- History

More Sources of Information

- American Geological Institute
  4220 King Street
  Alexandria, VA 22302

- American Institute of Professional Geologists
  7828 Vance Drive
  Suite 103
  Arvada, CO 80003

- American Association of Petroleum Geologists
  P. O. Box 979
  Tulsa, OK 74101

- Geological Society of America
  3300 Penrose Place
  Box 9140
  Boulder, CO 80301

METEOROLOGIST

Nature of the Occupation

Meteorologists study the atmosphere which surrounds the earth. They engage both in basic research to expand our knowledge of the earth's atmosphere and in activities relating its application to such areas as agriculture, transportation, communication, health, the environment, and national defense.

Duties may include but are not limited to the following:

- Analyzing and interpreting meteorological data gathered by surface and upper air stations, satellites, and radar
- Preparing weather forecasts for the media and other users
- Interpreting charts, maps, and other data in relation to such areas as barometric pressure, temperature, humidity, wind velocity, and areas of precipitation
- Conducting research for long-range forecasting
- Forecasting immediate and long-range weather changes on the basis of collected data
- Directing forecasting services at a weather station

NORTH CA TEMPS
82
65.
49.

Working Conditions

Meteorologists usually work in large field offices (meteorological stations) that are generally located at airports or near large cities; some are in isolated and remote areas.

Meteorologists in large field offices work with technicians or other meteorologists depending on the particular position. Some meteorologists may supervise assistants or technicians, and those working at small weather stations may work alone.

Generally, meteorologists work a 5-day, 40-hour week. Those working in weather stations that are in operation 7 days a week and 24 hours a day often work nights and weekends on rotating shifts.

Meteorologists may join professional associations such as the American Meteorological Society. Society members pay periodic membership dues.

Tools, Equipment and Materials used may include:

- Weather Maps & Charts
- Computers
- Technical Instruments for Recording Temperature, Humidity, Wind Direction and Speed, Rainfall, and Air Pressure

Worker Requirements

You should like:

- Performing work and solving problems of a scientific and technical nature
- Performing work which is abstract
- Performing work which requires creativity

You should be able to:

- Reason logically
- Make decisions based on personal judgment and measurable data
- Perceive details and be able to see differences in the paths of still and moving objects
- Communicate thoughts effectively
- Understand and use charts, graphs, and mathematical concepts

Physically you must:

- Have good vision, either naturally or with correction

Special Requirements:

A four-year college degree is required to enter this occupation. For research and teaching, advanced degrees are usually suggested.

OCCUPATION SPECIALTIES
DOT CODE:
025.062-010 Meteorologist
SOC CODE: 1846

OKLAHOMA
CAREER
SEARCH

METEOROLOGIST

Opportunities for Experience:

Meteorologists may gain experience in any branch of the military. Summer jobs, advanced training or enrollment in a cooperative education program at the National Oceanic and Atmospheric Administration are other avenues for exploration.

Methods of Entry:

Methods of entry include applying directly to employers and taking civil service examinations. Assistance in locating a position may be available through college and university placement offices.

Earnings and Advancement

Earnings of meteorologists depend on experience, ability, level of education, and on the type of employer.

Earnings:

Nationally, in 1987, meteorologists in training positions earned salaries ranging from $13,250 to $27,000. Meteorologists in research, instruction, and weather forecasting earned an average yearly salary of $35,500. Meteorologists who ran weather stations and taught in colleges and universities earned between $30,550 and $65,000 per year. Senior research scientists, consultants, and those with supervisory and/or administrative posts earned between $48,500 and $90,000 in 1987.

Meteorologists graduating with a bachelor's degree and employed by the Federal Government earned between $14,822 and $18,358 in 1987. Those with a master's degree earned salaries ranging from $18,358 to $22,458, and those with a Ph.D. earned between $27,172 and $32,567. Federally employed meteorologists earned an average salary of $39,700 in 1987.

Fringe Benefits:

Depending on the employer, meteorologists receive health and life insurance; paid vacations and holidays; retirement plans; and paid expenses for additional education.

Career Ladder for this Occupation may look like this:

- Area Forecaster/Office Supervisor
- Forecaster
- Assistant Forecaster
- Meteorological Trainee

Employment and Outlook

There were approximately 5,600 meteorologists employed nationally in 1987. Employment is expected to grow faster than the average rate for all occupations through the year 2000. Significant growth in employment is expected in the National Weather Service, which employs most meteorologists. Some new jobs will be created in private industry as firms recognize the value of having their own weather forecasting and meteorological services, but most of the job openings in this very small occupation will arise from the need to replace those who change occupations or leave the labor force for other reasons. Persons with an advanced degree in meteorology should have the best job prospects.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:

- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:

- College Preparatory
- Algebra
- Geometry
- Trigonometry
- General Science
- Physics
- English
- Computer Science
- Statistics
- Chemistry
- Physical Science
- Geography

More Sources of Information

- International Bio-Environmental Foundation
  c/o Steven Ross
  15300 Ventura Boulevard
  Suite 405
  Sherman Oaks, CA 91405

- American Meteorological Society
  45 Beacon Street
  Boston, MA 02108

- National Weather Association
  4400 Stamp Road
  Room 404
  Temple Hills, MD 20748

- National Weather Service Employees Organization
  400 N. Capitol Street
  Suite 326
  Washington, DC 20001

- National Weather Service/Personnel
  1-RAS / DC 23
  Rockville, MD 20782

- Federal, State, and Local Civil Service Offices

GROUP 1: SCIENTISTS

PART B: LIFE SCIENTISTS

BIOLOGICAL SCIENTIST

Nature of the Occupation

Biological scientists study the development, life processes, physiology, structure, heredity, environment and distribution of plants and animals to determine their economic value in such areas as farming, forestry, horticulture and pharmacology.

Duties may include but are not limited to the following:

- Studying the nature and behavior of plant and animal cells, chromosomes and tissues
- Identifying and classifying plants and animals
- Examining the effects of environmental factors on plant and animal growth
- Investigating the mechanics and chemistry of plant and animal life processes
- Developing new types of plants

Occupation Specialties

(Dot codes in parenthesis)

Economic Botanists (041.061-038) develop under controlled conditions wild and cultivated plants which prove to be valuable as crops.

Plant Taxonomists (041.061-038) identify and classify flowers, leaves, seeds or whole plants.

Mycologists (041.061-062) study fungi to determine the way they live and grow.

Plant Pathologists (041.061-086) conduct research in the nature, cause, and control of plant diseases and decay of plant products.

Biochemists (041.061-026) perform research on living organisms to develop a greater understanding of the chemical combinations and reactions involved in metabolism, reproduction, growth and heredity.

Microbiologists (041.061-058) examine the characteristics of living organisms. Some specialize as medical microbiologists and study the relationship between bacteria and disease.

Physiologists (041.061-078) study life functions of plants and animals under normal and abnormal conditions.

Botanists (041.061-038) conduct research on plants and their environments. They identify and classify plants and determine the cause and cure of disease.

Working Conditions

Biological scientists may work alone or as a member of a research team under the direction or supervision of a department head, research supervisor or a more experienced botanist. They may work outside in all kinds of weather when conducting field research or inside in laboratories, classrooms or museums.

Biological scientists employed by private industry usually work 40 hours a week. Overtime may be required to meet deadlines or complete a project.

Biological scientists may join associations such as the Botanical Society of America, American Society for Horticultural Science, and the American Society of Plant Physiologists. Members usually pay dues.

OCCUPATION SPECIALTIES

DOT CODE:

041.061-038	Botanist	041.061-038	Economic Botanist
041.061-062	Mycologist	041.061-038	Plant Taxonomist
041.061-026	Biochemist	041.061-086	Plant Pathologist
041.061-078	Physiologist	041.061-058	Microbiologist

SOC CODE: 1854

OKLAHOMA CAREER SEARCH

BIOLOGICAL SCIENTIST

Tools, Equipment and Materials used may include:
- Electron Microscopes
- Amino Acid Analyzers
- Radioactive Isotopes
- Microscopes
- Manuals and Reference Materials
- Scientific Equipment

Worker Requirements

You should like:
- Working with things and objects
- Performing work of a scientific and technical nature
- Performing activities of an unusual, indefinite nature which require creative imagination

You should be able to:
- Perform a variety of duties which may often change
- Work within precise limits or standards of accuracy
- Rate information by using personal judgment and measurable standards
- Work effectively with other people

Physically you must:
- See well, either naturally or with correction
- Reach, handle, finger and feel objects
- Be able to stoop, kneel, crouch and crawl

Special Requirements:

Educational requirements vary according to the job. Those with a bachelor's or master's degree can work as field or laboratory technicians. Persons interested in doing independent research or teaching at the university level should have a Ph.D. degree.

Methods of Entry:

Methods of entering this occupation include direct application to employers and civil service offices. Positions may also be located by consulting college and university placement offices.

Earnings and Advancement

Earnings depend upon the employer, geographic location and employee's education and level of responsibility.

Earnings:

In 1987, biological scientists graduating with a bachelor's degree earned a starting salary of $19,000. Those graduating with a master's degree earned a starting salary of $22,000.

Biological scientists graduating with a bachelor's degree and employed by the Federal Government earned salaries ranging from $14,822 to $18,358 in 1987. Those graduating with a master's degree earned salaries between $18,358 and $22,458. Ph.D. graduates earned salaries ranging from $27,172 to $32,567 in 1987.

Fringe Benefits:

Depending on the employer, biological scientists may receive paid vacations and holidays; life, accident, disability and hospitalization insurance; retirement plans; and sick pay. These benefits are usually paid for, at least in part, by the employer.

Employment and Outlook

There were approximately 111,000 biological scientists employed nationally in 1987. Employment is expected to increase as fast as the average for all occupations through the year 2000. Employment opportunities for biological scientists, who specialize in genetics and biotechnical research, are good in the private industry sector.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:
- Agricultural Production/ Management
- Ornamental Horticulture
- Algebra
- Chemistry
- Physics
- Forestry
- College Preparatory
- Biology
- General Science

More Sources of Information

- American Society of Plant Physiologists
  15501 Monona Drive
  Rockville, MD 20855

- American Society for Horticultural Science
  701 North Saint Asaph Street
  Alexandria, VA 22314

- Botanical Society of America
  Biology Dept.
  c/o David L. Dilcher
  Indiana University
  Bloomington, IN 47405

- American Institute of Biological Sciences
  730 11th Street, NW
  Washington, DC 20001-4584

- Federal, State or Local Civil Service Offices

PHYSICIAN

Nature of the Occupation

Physicians diagnose and treat human diseases and injuries as well as practice preventive medicine. Physicians may be doctors of allopathic medicine (M.D.) or doctors of osteopathic medicine (D.O.).

Duties may include but are not limited to the following:

- Examining patients
- Ordering or performing various tests, analyses and x-rays
- Prescribing and administering drugs and treatments
- Inoculating and vaccinating patients
- Providing prenatal and postnatal care
- Delivering babies
- Performing surgery and related procedures
- Instructing individuals and organizations in ways to preserve health and prevent disease
- Performing research to aid in control and cure of disease
- Developing and testing new medical techniques
- Investigating new drugs and medications

Occupation Specialties

(Dot codes in parenthesis)

Surgeons (070.101-094) perform operations to correct deformities, repair injuries, prevent diseases, and improve body functions in patients.

Pediatricians (070.101-066) specialize in the diagnosis and treatment of children's diseases from birth through adolescence.

Obstetricians and Gynecologists (070.101-054, 070.101-034) specialize in the care and treatment of women during and immediately following pregnancy and in diseases of the female reproductive organs.

Cardiologists (070.101-014) diagnose and treat diseases of the heart.

Psychiatrists (070.107-014) study, diagnose, and treat mental, emotional, and behavioral disorders.

Podiatrists (079.101-022) diagnose and treat disorders and diseases of the foot and lower leg.

Working Conditions

Physicians may work alone, with other physicians or with the nursing staff. They may supervise interns or residents along with the nursing staff. Physicians generally work in well-lighted and ventilated hospitals, clinics, nursing homes, or offices. They may be exposed to infection from patients, and radioactivity from x-rays.

Hospital or clinical physicians usually work one of three shifts. Private practice physicians generally maintain regular office hours and an emergency answering service.

Physicians may join associations such as the American Medical Association or the American Osteopathic Association. Members pay dues.

Tools, Equipment and Materials used may include:

- Medical Lab Equipment
- X-ray Equipment
- Surgical Equipment, such as Scalpels, Forceps & Clamps
- Stethoscopes
- Electrocardiographs

OCCUPATION SPECIALTIES

DOT CODE:

070.101-022	General Practitioner
071.101-010	Osteopathic Physician
070.101-094	Surgeon
070.101-054	Obstetrician
070.101-034	Gynecologist
070.101-066	Pediatrician
070.101-014	Cardiologist
070.107-014	Psychiatrist
079.101-022	Podiatrist

SOC CODE: 261

OKLAHOMA
CAREER
SEARCH

PHYSICIAN

Worker Requirements

You should like:
- Activities of a scientific and technical nature
- Helping and working with people
- Working with detail
- Variety, requiring the use of different skills
- Working independently

You should be able to:
- Reason clearly and logically
- Work cooperatively with and direct the activities of others
- Make evaluations and decisions based on judgment and data
- Perceive detail in objects, pictures, or graphs
- Communicate effectively in speech and writing

Physically you must:
- See well, naturally or corrected, with good color vision
- Talk and hear
- Have full use of hands and fingers
- Possess excellent eye, hand, and finger coordination

Special Requirements:

All fifty states, the District of Columbia, and Puerto Rico require physicians to be licensed to practice medicine. Requirements for licensing are graduation from an accredited medical school, internship and passing a state medical exam. Most states grant reciprocity for licensing.

Most states now require physicians to have 150 hours of continuing education credits every three years for license reregistration.

Methods of Entry:

In 1982, 84 percent of all physicians were involved in patient care, with the majority in private practice. Positions with hospitals, clinics, federal and state agencies, and universities may be located by consulting professional journals and medical school placement offices.

Earnings and Advancement

Earnings depend upon whether the physician is salaried or in private practice, the geographic location, higher professional reputation, and length of experience.

Earnings:

Nationally, in 1987, physicians in residency earned salaries ranging between $20,000 and $24,000. Established physicians earned an average yearly salary of approximately $106,300.

Physicians employed at veterans administration hospitals earned an average salary of $46,800 in 1987.

Career Ladder for this Occupation may look like this:
- Administrator
- Physician
- Intern or Resident

Physicians may advance through experience and professional competence and demonstrated administrative ability.

Employment and Outlook

There were approximately 535,000 physicians employed nationally in 1987. Employment is expected to grow faster than the average as demand for health care continues to outpace overall economic growth. Newly trained physicians are likely to experience competition as they seek to launch a practice. Those who are willing to locate in inner cities, rural areas, and other places where doctors are not in oversupply should have little difficulty.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Physiology
- Geometry
- Trigonometry
- Chemistry
- Physics
- Psychology
- English
- Algebra
- Statistics
- Biology
- Physical Science
- Humanities
- Sociology

More Sources of Information

- American Medical Association
  535 North Dearborn Street
  Chicago, IL 60610-4377

- American Medical Women's Association
  465 Grand Street
  New York, NY 10002

- American Osteopathic Association
  212 East Ohio Street
  Chicago, IL 60611

PSYCHOLOGIST

Nature of the Occupation

Psychologists study the behavior of people and animals in order to understand and explain the way they react and respond. They may be concerned with people's emotions, stress, and abnormal behavior. Some teach while others work in private practices or for institutions.

Duties may include but are not limited to the following:

- Diagnosing and treating psychological problems
- Collecting data by using interviews, case histories, observational techniques, and other methods
- Administering and interpreting psychological tests
- Counseling people individually and in groups
- Conferring with parents, counselors, administrators, and others
- Determining the effectiveness of treatments
- Developing and evaluating mental health or other programs

Occupation Specialties

(Dot codes in parenthesis)

Clinical Psychologists (045.107-022) diagnose and treat mentally and emotionally disturbed people.

Counseling Psychologists (045.107-026) provide counseling to help people achieve more effective development.

Educational Psychologists (045.067-010) develop psychological principles and techniques that apply to educational problems.

School Psychologists (045.107-034) evaluate children within an educational system and plan and implement corrective programs.

Psychometrists (045.067-018) administer, score, and interpret intelligence, aptitude, achievement, and other psychological tests.

Developmental Psychologists (045.061-010) investigate emotional, mental, physical, and social changes throughout peoples' lives.

Experimental Psychologists (045-061-018) conduct experiments related to human and animal behavioral processes such as motivation and perception.

Industrial Organizational Psychologists (045.107-030) develop and apply psychological techniques to administration, management, and marketing problems.

Working Conditions

Psychologists may work alone or as part of a team with other psychologists, psychiatrists, physicians, and other specialists. They may also work with parents, teachers, counselors, administrators, and others.

Work settings vary from classroom and laboratories to hospitals, correctional institutions, clinics, private offices, and factories. Surroundings are generally comfortable and well-equipped.

Working hours and schedules vary with the psychologist's specialization. Those who teach or work for government agencies and institutions usually work 35-40 hours a week. Those in private practice arrange their own schedules.

Many psychologists choose to belong to professional associations such as the American Psychological Association or the National Mental Health Association. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Computers
- Surveys
- Tests
- Audio-Visual Materials
- Questionnaires

Worker Requirements

You should like:

- Activities of a scientific and technical nature
- Activities concerned with the

OCCUPATION SPECIALTIES

DOT CODE:

045.107-022	Psychologist, Clinical
045.107-026	Psychologist, Counseling
045.067-010	Psychologist, Educational
045.107-034	Psychologist, School
045.067-018	Psychometrist
045.061-010	Psychologist, Developmental
045.061-018	Psychologist, Experimental
045.107-030	Psychologist, Industrial-Organizational

SOC CODE: 1915

OKLAHOMA
CAREER
SEARCH

PSYCHOLOGIST

communication of ideas
- Activities which involve direct contact with people

You should be able to:
- Perform a variety of duties which may change often
- Reason logically
- Understand the meanings and relationships of words
- Rate information using personal judgment or standards
- Communicate effectively in speech and writing
- Work well under pressure

Physically you must:
- Talk, hear, and see, depending on specialization

Special Requirements:

All fifty states and the District of Columbia have licensing or certification requirements for psychologists.

Opportunities for Experience:

Few opportunities exist for high school students to explore careers in psychology. Related work experience may be obtained in branches of the military service.

Methods of Entry:

Apply directly to employers and civil service offices. Placement offices are also helpful. In addition, the American Psychological Association publishes a monthly bulletin for its members which lists job openings.

Earnings and Advancement

Earnings depend on the employer, the individual's experience, and level of education. Those having Ph.D. degrees earn more than those with master's degrees. Psychologists with Ph.D. degrees in private practice generally have higher earnings than those in academic settings as do those in administrative positions.

Earnings:

Psychologists with a doctoral degree earned a median annual salary of approximately $39,500 in 1987. Those employed by state and local governments earned an annual salary of about $32,900 and $30,700, respectively; by hospitals and clinics, about $35,900; by other nonprofit organizations, about $34,400; by business and industry, about $50,000; and in educational institutions, about $37,600. Psychologists graduating with a bachelor's degree and employed by the Federal Government earned salaries ranging from $14,800 to $18,400 in 1987. The average salary for psychologists working for the Federal Government was approximately $41,400 in 1987.

Fringe Benefits:

Most psychologists receive life insurance, health insurance, vacations, and retirement plans. These benefits may be paid for, at least in part, by the employer.

Employment and Outlook

Nationally, in 1987, there were approximately 110,000 psychologists employed. Employment is expected to grow faster than the average through the year 2000. Graduates face increasing competition, particularly for academic positions. The best prospects will be available for doctoral degree holders trained in applied areas such as clinical, counseling health, engineering, and industrial psychology. Persons with only a master's degree will probably continue to encounter severe competition. Nevertheless, some may find jobs as counselors in schools or as assistants in community mental health centers. Bachelor degree holders can expect very few opportunities in this field, although some may find jobs as assistants in rehabilitation centers.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:
- College Preparatory
- English
- Algebra
- Social Studies
- Psychology
- Sociology
- Composition
- Child Growth & Development
- Statistics

More Sources of Information

- American Psychological Association
  1200 17th Street, NW
  Washington, DC 20036

- American Association for Counseling & Development
  5999 Stevenson Avenue
  Alexandria, VA 22304

- National Mental Health Association
  1021 Prince Street
  Alexandria, VA 22314-2971

- National Association of School Psychologists
  P. O. Box 557
  Southfield, MI 48037

DIETITIAN & NUTRITIONIST

Nature of the Occupation

Dietitians apply the principles of nutrition to plan and supervise the preparation and serving of meals in hospitals, schools, restaurants and other public and private institutions.

Duties may include but are not limited to the following:
- Supervising the planning, preparation and service of meals
- Selecting, training and directing food-service workers
- Providing diet counseling services
- Coordinating dietary services with those of other departments
- Acting as a consultant to management
- Preparing records and reports

Occupation Specialties

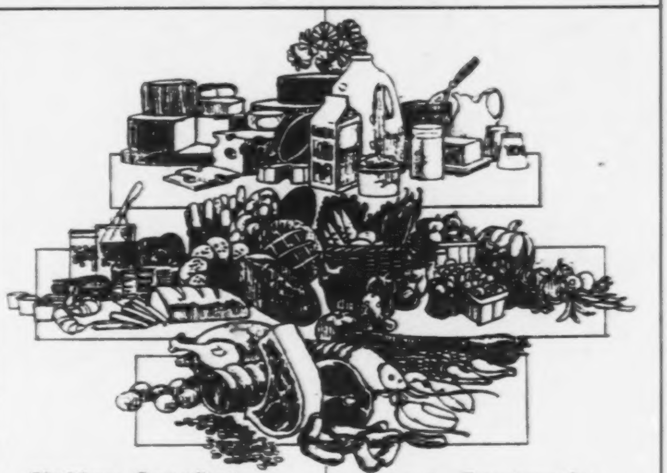
(Dot codes in parenthesis)

Dietitians, Chief (077.117-010) plan, organize and direct food service programs and nutritional care for establishments requiring large-scale meal planning and preparation.

Dietitians, Clinical (077.127-014) plan and direct the preparation and service of diets prescribed by a physician.

Dietitians, Research (077.061-010) conduct, evaluate and interpret research to improve the nutrition of both healthy and sick people.

Community Dietitians (077.127-010) plan develop, administer and coordinate nutrition programs and services as part of the health care services for an organization.



Dietitians, Consultant (077.127-018) advise and assist public and private establishments, such as child care centers, hospitals, nursing homes and schools on food service management, nutritional education programs and nutritional problems.

Working Conditions

Clinical, research and consulting dietitians may work alone or as part of a health team. Community dietitians work with a health team, and administrative dietitians supervise others.

Dietitians may perform their duties in comfortable, well-lighted and well-ventilated offices, at patient's bedsides, in small crowded clinic rooms or in modern, well-equipped kitchens or research laboratories.

Dietitians generally work 8 hours a day, 5 days a week. Shift, evening, weekend and holiday work may be required in some hospitals, institutions and restaurants. Travel may be required for consulting dietitians.

Dietitians may join professional associations such as the American Dietetic Association or the American Society for Hospital Food Service Administrators. Members usually pay dues.

Tools, Equipment and Materials used may include:
- Diet Menus
- Diet Orders
- Diet Manuals
- Nutrition Books
- Nutritional Assessment Forms
- Scales
- Food Models

Worker Requirements

You should like:
- Activities of a scientific and technical nature
- Helping people

You should be able to :
- Perform a variety of duties which may often change
- Use logical step-by-step

OCCUPATION SPECIALTIES

DOT CODE:

077.117-010	Dietitian, Chief
077.127-014	Dietitian, Clinical
077.061-010	Dietitian, Research
077.127-010	Community Dietitian
077.127-018	Dietitian, Consultant

SOC CODE: 302

OKLAHOMA CAREER SEARCH

DIETITIAN & NUTRITIONIST

procedures to complete tasks
- Analyze and solve problems based upon accurate information
- Work and communicate well with a variety of people
- Direct, control and plan activities
- Perform mathematical calculations

Physically you must:
- See well, either naturally or with correction, including color vision
- Talk and hear

Special Requirements:
Many employers prefer to hire dietitians who are registered with the American Dietetic Association. Registration (designated by RD) can be obtained by passing the national exam. Membership is granted after completion of a combination of educational requirements, internship, and approved work experience.

Opportunities for Experience:
Part-time or summer employment in hospitals or restaurants may provide helpful experience in this area.

Methods of Entry:
Methods of entering this occupation include direct application to employers, civil service exams, college placement offices and the American Dietetic Association. Positions may also be located by consulting newspaper want ads, professional journals or your state employment office.

Earnings and Advancement

Earnings depend upon the employer and the individual's education, work experience and type of position held.

Earnings:
Nationally, in 1987, beginning dietitians earned yearly salaries averaging $20,400. Experienced hospital dietitians averaged $26,600. Beginning dietitians employed by the Federal Government earned and average of $14,821 in 1987. Dietitians with experience earned an average of $29,300.

Fringe Benefits:
Depending on the employer, dietitians may receive paid vacations and holidays; sick leave; insurance; and retirement plans. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Chief Dietitian or Department Director
- Dietitian

Dietitians may advance through experience, seniority, further education, demonstration of leadership ability of civil service exams.

Employment and Outlook

There were approximately 40,000 dietitians employed nationally in 1987. Employment is expected to grow faster than the average through the year 2000 in response to increasing concern for proper nutrition. Favorable opportunities are expected, both full-time and part-time, for those having appropriate training and clinical experience.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- High school diploma with vocational education

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Physiology
- Food Service
- Biology
- Sociology
- Health Education
- Cooperative Education - Home Economics
- Foods & Nutrition
- Chemistry

More Sources of Information

- American Dietetic Association
  430 North Michigan Avenue
  Chicago, IL 60611

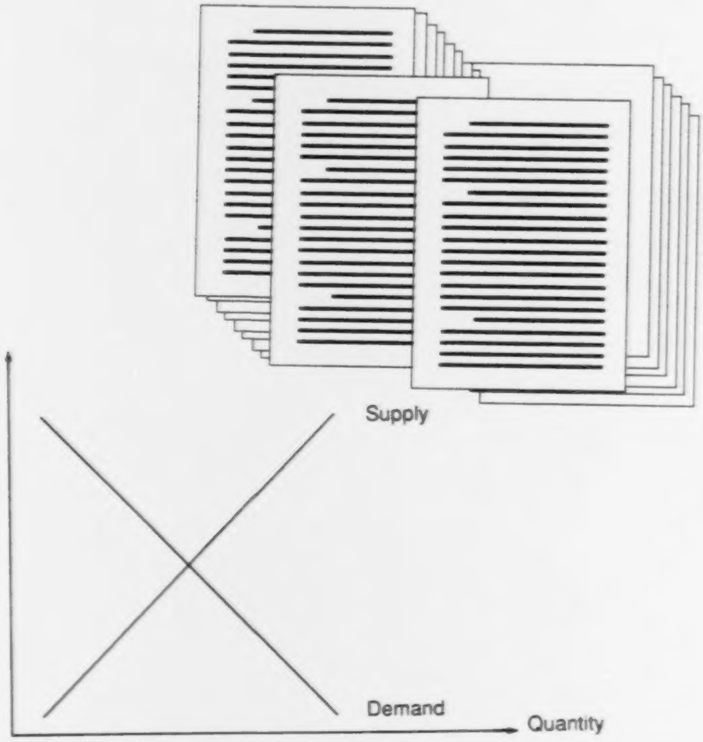
- American Society for Hospital Food Service Administrators
  American Hospital Association
  840 North Lake Shore Drive
  Chicago, IL 60611

- American Institute of Nutrition
  9650 Rockville Pike
  Bethesda, MD 20814

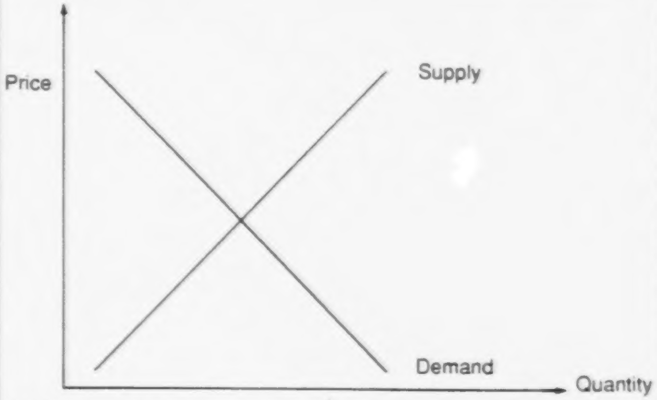
- Federal, State and Local Civil Service Offices

GROUP 1: SCIENTISTS

PART C: SOCIAL SCIENTISTS


Supply
Demand
Quantity

ECONOMIST



Nature of the Occupation

Economists conduct research, prepare reports, and formulate plans to aid in the solution of economic problems arising from the production and distribution of goods and services.

Duties may include but are not limited to the following:
- Developing methods for collecting and processing economic and statistical data
- Interpreting economic and statistical data
- Analyzing the relationships between the supply and demand for goods and services
- Developing ways to control inflation, unemployment and business cycles
- Planning and conducting studies to determine the need for change in business or government policy

Occupation Specialties

(Dot codes in parenthesis)

Market Research Analysts (050.067-014) study conditions in sales areas to determine the sales projections of a product or service.

Agricultural Economists (050.067-010) study agricultural problems to determine better uses of farm resources.

Tax Economists (050.067-010) collect and study data and the effects of taxes and policies on national income and overall business activities.

Labor Economists (050.067-010) collect and interpret labor data to forecast labor trends and suggest changes in labor policies.

Industrial Economists (050.067-010) study the organizational structure, methods of financing, production costs and techniques, and marketing policies of various types of businesses to develop improvements.

Working Conditions

Economists working in private industry may work alone, with members of other professions, or with company officers. Economists usually work in comfortable, well-lighted and air-conditioned offices.

Economists in private industry generally work a 5-day, 40-hour week. Although most work under the pressure of deadlines, tight schedules, and heavy workloads, economists may also sometimes must work overtime. They may also be required to travel to attend conferences or conduct research.

Economists teaching on the college level have flexible work schedules, dividing their time among teaching, research, and administrative duties.

Economists may join associations such as the American Economic Association, the Econometric Society, and the National Association of Business Economists. Members usually pay dues.

Tools, Equipment and Materials used may include:
- Computers
- Calculators
- Statistical & Other Reports
- Text & Reference Books

Worker Requirements

You should like:
- Working with technical and theoretical data
- Work concerned with people and the communication of information

You should be able to:
- Analyze economic information
- Make decisions based on judgment and experience or on verifiable and measurable data

OCCUPATION SPECIALTIES

DOT CODE:

050.067-010	Economist
050.067-014	Market Research Analyst
050.067-010	Agricultural Economist
050.067-010	Tax Economist
050.067-010	Labor Economist
050.067-010	Industrial Economist

SOC CODE: 1912

OKLAHOMA
CAREER
SEARCH

ECONOMIST

- Understand mathematical and statistical methods
- Reason logically
- Communicate clearly and effectively in speech and in writing
- Plan, direct and control economic studies

Physically you must:
- See well, either naturally or with correction
- Have normal speaking and hearing ability

Opportunities for Experience:
Summer or part-time employment doing research for universities, the government, or business firms may provide helpful experience.

Methods of Entry:
Methods of entering this occupation include direct application to employers and taking civil service exams. Positions may also be located by consulting professional journals, college placement offices, and state employment offices.

Earning and Advancement

Earnings depend upon the employer, type of work, geographic location, and the education and experience of the employee.

Earnings:
Nationally, in 1987, economists graduating with a bachelor's degree earned a starting salary of $22,400. Median annual earnings of full-time economists were about $36,600. The median base salary of business economists was $54,000. Economists in general administration and international economics earned the highest salaries, those in market and research and econometrics the lowest. The highest paid business economists were in the securities and investment, retail and wholesale trades, and insurance industries; the lowest paid were in education, nonprofit research organization, and real estate.

Economists graduating with a bachelor's degree and employed by the Federal Government earned a starting salary between $14,800 and $18,400 in 1987. Those with a master's degree earned a starting salary of $22,500, while Ph.D. graduates earned a beginning salary of approximately $28,000.

Career Ladder for this Occupation may look like this:
- Economic Advisor
- Economist
- Market Research Analyst

Economists may advance through experience, responsibilities or administrative duties.

Employment and Outlook

There were approximately 37,000 economists employed nationally in 1987. Employment is expected to grow faster than the average through the year 2000. Best opportunities are available for those trained in quantitative methods. Ph.D.'s face competition for academic positions, but can expect good opportunities in nonacademic areas. Persons with master's and bachelor's degrees are likely to face keen competition for economist jobs, but many will find research, managerial, and administrative positions.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Calculus
- Geometry
- Trigonometry
- Business Data Processing
- Government
- Political Science
- Algebra
- Computer Science
- Statistics
- Accounting
- Economics
- History
- Sociology

More Sources of Information

- American Economic Association
  1313 21st Avenue South
  Nashville, TN 37212

- Econometric Society
  Department of Economics
  Northwestern University
  Evanston, IL 60201

- Joint Council on Economic Education
  2 Park Avenue
  New York, NY 10016

- National Association of Business Economists
  28349 Chagrin Boulevard
  Cleveland, OH 44122

- Federal, State, and Local Civil Service Offices

- College and University Placement Offices

SOCIOLOGIST

Nature of the Occupation

Sociologists study the behavior and interaction of groups and trace their origin and growth and analyze the influence of group activities on individual members.

Duties may include but are not limited to the following:

- Collecting and analyzing scientific data concerning social phenomena
- Directing research
- Preparing technical publications
- Teaching and lecturing
- Acting as consultants

Occupation Specialties

(Dot codes in parenthesis)

Criminologists (054.067-014) specialize in research on the relationships between criminal law, social order, and causes of crime.

Industrial Sociologists (054.067-014) specialize in research on group relationships and processes in an industrial organization.

Penologists (054.067-014) specialize in research of punishment for crime, control and prevention of crime, management of penal institutions, and criminal rehabilitation.

Rural Sociologists (054.067-014) specialize in research on more rustic, agricultural communities, and special problems brought on by scientific and industrial changes in the rural way of life.

Urban Sociologists (054.067-014) specialize in research on the origin, growth, structure, and demographic characteristics (population statistics) of cities.

Medical Sociologists (054.067.014) specialize in research on social factors affecting health care, including patient and physician behavior, and the delivery of health care.

Demographers (054.067-014) conduct research, surveys, and experiments to study human populations and population trends.

Working Conditions

Sociologists generally work alone under the general supervision of a department head or research director. They usually work inside in clean, well-lighted, and ventilated offices, classrooms, and experimental laboratories. Some sociologists, such as rural sociologists, spend considerable time outside in all kinds of weather.

Sociology faculty members have flexible work schedules, dividing their time between teaching, research, consulting, and administrative responsibilities. Sociologists working in government agencies and private firms have structured work schedules. Many sociologists experience the pressures of deadlines, heavy workloads, and overtime. Travel may be required to collect data for research projects or attend professional conferences. Sociologists in private practice may work evenings and weekends to accommodate clients.

Sociologists may join organizations such as the American Sociological Association. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Calculators
- Questionnaires & Other Survey Materials
- Manuals
- Computer Equipment
- Charts
- Diagrams
- Publications

Worker Requirements:

You should like:

- Communicating ideas to others
- Activities of a scientific and technical nature
- Activities of an abstract and creative nature

You should be able to:

- Plan, direct, and control an entire activity and the activities of others
- Evaluate information according to sensory or judgmental criteria
- Express yourself well orally and in writing

Physically you must:

- Speak and hear

Opportunities for Experience:

Because of the educational requirements there are few ways to explore or gain experience within the occupation. Work with ethnic groups or programs such as **VISTA** will provide some opportunities.

Methods of Entry:

Methods of entering this occupation include direct application to colleges and universities and civil service offices.

OCCUPATION SPECIALTIES

DOT CODE:

054.067-014	Sociologist	054.067-014	Rural Sociologist
054.067-014	Criminologist	054.067-014	Urban Sociologist
054.067-014	Industrial Sociologist	054.067-014	Medical Sociologist
054.067-014	Penologist	054.067-014	Demographer

SOC CODE: 1916

OKLAHOMA
CAREER
SEARCH

SOCIOLOGIST

Earnings and Advancement

Earnings depend upon the employer, geographic location, and the individual's education.

Earnings:

Nationally, in 1987, sociologists and anthropologists earned a median annual salary of $37,200. Sociologists employed in educational institutions earned a median salary of $37,000; in state and local government, $40,400; and in business and industry, $45,000.

Sociologists employed by the Federal Government graduating with a bachelor's degree earned starting salaries ranging from $14,800 to $18,400 in 1987. Those graduating with a master's degree earned a starting salary of approximately $22,500. Ph.D. graduates earned a starting salary of about $27,200 to $32,600.

Fringe Benefits:

Depending on the employer, sociologists may receive paid vacations and holidays; life, accident, disability, and hospitalization insurance; retirement plans; and sick pay. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:

Sociologists who teach may advance after gaining additional experience and education and developing a reputation for distinctive work or publications.

Employment and Outlook

Several thousand sociologists were employed nationally in 1987. The demand for sociologists should be spurred by research in various fields. Increased demand for sociologists is likely to arise from the need to evaluate and administer programs designed to cope with social and welfare problems. The number of persons who graduate with advanced degrees in sociology through the year 2000 is likely to greatly exceed the available job openings.

Graduates with a Ph.D. face increasing competition, particularly for academic positions. Best opportunities exist for graduates with a Ph.D. trained in quantitative research techniques and applied sociology. Persons with master and bachelor degrees will continue to face strong competition for job openings.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation:

- College bachelor's degree

School subjects helpful in preparing for this occupation include:

- College Preparatory
- Algebra
- Statistics
- Economics
- History
- Psychology
- Sociology
- English
- Computer Science
- Trigonometry
- Political Science
- Social Studies

More Sources of Information

- Rural Sociological Society
  Wilson Hall
  Montana State University
  Bozeman, MT 59717

- Sociological Practice Association
  c/o Dr. Elizabeth Clark
  R.D. 2, Box 141A
  Chester, NY 10918

- American Sociological Association
  1722 N Street, NW
  Washington, DC 20036

- Sociology of Education Association
  1538 Liberty Street
  El Cerrito, CA 94503

- College and University Placement Offices

GROUP 1: SCIENTISTS

PART D: MATHEMATICIANS

COMPUTER PROGRAMMER

Nature of the Occupation

Computer programmers write step-by-step instructions for computers. These programs, written in special computer languages, tell the computer exactly what it must do to solve a problem. Programmers often are grouped into broad types: applications programmers, who write software to handle specific jobs such as inventory control; and systems programmers, who maintain the software that controls the operation of the entire computer system.

Duties may include but are not limited to the following:

- Studying problems and determining the steps necessary to solve them
- Writing out the steps involved in 'flow-chart' form (diagram)
- Writing out details for each step in a computer language
- Checking to make sure the instructions are correct and will produce the desired results (debugging)
- Rewriting programs if desired results are not produced
- Modifying existing programs to meet new requirements
- Preparing an instruction sheet for use of the program

Occupation Specialties

(Dot codes in parenthesis)

Business Programmers (020.162-014) develop programs for administrative or business problems in a computer language.

Engineering and Scientific Programmers (020.167-022) write programs to solve engineering or scientific problems by applying a knowledge of advanced mathematics and an understanding of the computer.

Information Systems Programmers (020.187-010) develop and write computer programs to store, locate, and retrieve specific documents, data, and information used in science, education, law, libraries, etc.

Process Control Programmers (020.187-014) plan and write computer programs for control systems that automate operations for the complete sequence of machine instructions and routines necessary to complete the processing cycle.

Working Conditions

Computer programmers may work alone or as a member of a programming team under the direction or supervision of a more experienced programmer or manager. Programmers generally work in or near computer rooms in clean, well-lighted, well-ventilated offices.

Many programmers work 8 hours a day, 5 days a week. Some programmers frequently work evenings and/or nights when conputer time is most often available. Overtime may be required to complete a project or to meet a deadline.

Many computer programmers join a professional association. These include the American Federation of Information

OCCUPATION SPECIALTIES

DOT CODE:

020.162-014	Programmer, Business
020.167-022	Programmer, Engineering and Scientific
020.187-010	Programmer, Information System
020.187-014	Programmer, Process Control

SOC CODE: 3971

OKLAHOMA
CAREER
SEARCH

COMPUTER PROGRAMMER

Processing Societies and the Data Processing Management Association. They may pay periodic membership fees.

Tools, Equipment and Materials used may include:
- Computers
- Coding Sheets
- Terminals
- Optical Scanners
- Keypunch and Teletype Machines
- Magnetic Tapes, Punched Cards, and Magnetic Discs

Worker Requirements

You should like:
- Work that involves data and statistics
- Work that involves detail and accuracy

You should be able to:
- Think logically and be organized
- Follow set procedures
- Solve business and engineering problems
- Communicate well, both verbally and in writing

Physically you must:
- Have good vision and hearing, either naturally or with correction
- Have good manual and finger dexterity

Special Requirements:

Although many employers using computers for business applications do not require college degrees, applicants who have had related college courses are preferred.

Opportunities for Experience:

Persons interested in computer programming may gain experience in the military service. Many high schools, colleges, and universities also offer the opportunity for computer experience after some course work.

Methods of Entry:

Apply directly to employers. If you are interested in working for government agencies, you must take a civil service exam. Those who have taken college courses may receive help locating positions through college placement offices. Positions may also be located by consulting newspaper want ads.

Earnings and Advancement

The earnings of computer programmers depend on the complexity of the work they do and to some extent on the area of the state in which they work. Earnings tend to be slightly higher in large urban areas.

Earnings:

Median earnings of full-time programmers in 1987 was $27,000 a year. Experienced computer programmers have a potential of earning between $33,900 and $43,100 annually. The Federal Government entrance salary for programmers with a college degree was $14,800 a year in 1987.

Programmers in the North & West averaged more than those in the South. Those in manufacturing and public utilities earned more than those in industry. Systems programmers averaged more than applications programmers.

Fringe Benefits:

Programmers may receive vacation pay; retirement plans, health and life insurance; sick leave; profit-sharing plans; and dental insurance. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Programming Manager
- Senior Manager/Programmer
- Staff Programmer
- Junior Programmer
- Trainee

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- High school diploma with vocational education
- Technical junior or community college
- College bachelor's degree

Level(s) of education and training also available for this occupation:
- On-the-job training

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Computer Science
- Statistics
- Accounting
- Business Data Processing
- Typing
- English
- Calculus
- Geometry
- Trigonometry
- Bookkeeping
- Cooperative Education - Office/Distribution
- Office Practice
- Office Machines

More Sources of Information

- American Federation of Information Processing Societies
  1899 Preston White Drive
  Reston, VA 22091

- Data Processing Management Association
  505 Busse Highway
  Park Ridge, IL 60068

- Association for Systems Management
  24587 Bagley Road
  Cleveland, OH 44138

- Office Automation Society International
  15269 Mimosa Trail
  Dumfries, VA 22026

MATHEMATICIAN

Nature of the Occupation

Mathematicians deal with systems involving the relationship of quantities, magnitudes, and forms to conduct research and solve problems in other areas such as science and management.

Duties may include but are not limited to the following:

- Testing hypotheses and alternative theories
- Conceiving and developing ideas for the application of mathematics to a wide variety of areas
- Performing computations and applying methods of numerical analysis
- Operating or directing the operation of mechanical and electronic equipment in support of mathematical, scientific, or industrial research

Occupation Specialties

There are two types of professional mathematicians: those who work in pure or theoretical mathematics and those who work in applied mathematics. These two areas may overlap and are not always distinct in practice.

Working Conditions

Mathematicians often work closely with other professionals and specialists such as scientists, engineers, college staff members, computer scientists, or government officials. They usually work in quiet, comfortable offices, research laboratories, and classrooms.

Mathematicians usually work a regular 40-hour week. Evening and weekend work are common. Overtime may be required on special projects.

Mathematicians may join associations such as the American Mathematical Society, the Mathematical Association of America and the Society for Industrial and Applied Mathematicians. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Computers
- Calculators
- Analyzers
- Plotters

Worker Requirements

You should like:

- Activities of a scientific and technical nature
- Activities dealing with machines, processes, and techniques
- Working creatively with numbers and abstract symbols

You should be able to:

- Reason clearly and logically
- Make judgments based on measurable data and experience
- Visualize geometric forms and picture two-dimensional drawings as three-dimensional objects
- Perform complex mathematical operations with accuracy
- Understand the relationship between words and use them effectively
- Direct and plan an activity or the activities of others

Physically you must:

- Be able to reach for, handle, finger, and feel objects
- See well, either naturally or with correction

Special Requirements:

A bachelor's degree is needed, and is considered adequate preparation for some jobs in private industry and government. An advanced degree is a prerequisite for the more responsible positions, and a Ph.D. is often required for research positions. A master's degree is the minimum requirement to teach in most 2-year and a few 4-year colleges, but the Ph.D. is necessary to attain full faculty status.

Opportunities for Experience:

Summer employment under the direction of mathematicians or participation in school mathematics or science clubs may provide useful experience.

Methods of Entry:

Methods of entering this occupation include direct application to employers, college placement offices, and civil service offices. Positions may also be located by consulting newspaper want ads, scientific and professional journals, and state employment offices.

Earnings and Advancement

Earnings depend upon the type of employer, nature of the work, and employee's education and experience.

Earnings:

Nationally, in 1987, beginning mathematicians earned the

OCCUPATION SPECIALTIES
DOT CODE:
020.067-014 Mathematician
SOC CODE: 1739

MATHEMATICIAN

following average salaries: bachelor's degree--$24,400; master's degree--$30,600; and Ph.D.--$39,500. The average annual salary for all mathematicians was approximately $37,310 in 1987.

Mathematicians employed by the Federal Government in 1987 averaged the following salaries at various grade levels: bachelor's degree--$14,800 to $18,400; master's degree--$22,500 to $27,200; and Ph.D.--$27,200 to $32.600. The average salary for all mathematicians working for the Federal Government was approximately $38,100 in 1987.

Fringe Benefits:

Depending on the employer, mathematicians may receive paid vacations and holidays; group life and hospitalization insurance; sick leave; and pensions. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:

Mathematicians may advance into more responsible theoretical work or to management positions through experience and further education.

Employment and Outlook

There were approximately 49,000 mathematicians employed nationally in 1987. Employment of mathematicians is expected to grow about as fast as the average for all occupations through the year 2000. Best opportunities are available for holders of doctorate degrees, especially in applied mathematics and computer science. Those with bachelor's or master's degrees in mathematics may have difficulty finding a job in university teaching or theoretical research. However, there will be many openings in applied areas such as computer science and data processing.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- College bachelor's degree
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:

- College Preparatory
- Algebra
- Computer Science
- Statistics
- Chemistry
- Physics
- English
- Calculus
- Geometry
- Trigonometry
- General Science
- Economics

More Sources of Information

- American Mathematical Society
  Box 6248
  Providence, RI 02940

- Society for Industrial and Applied Mathematics
  1400 Architects Building
  177 South 17th Street
  Philadelphia, PA 19103

- Mathematical Association of America
  1529 18th Street, NW
  Washington, DC 20036

- National Council of Teachers of Mathematics
  1906 Association Drive
  Reston, VA 22091

COMPUTER SYSTEMS ANALYST

Nature of the Occupation

Computer systems analysts help define the computer process necessary to turn raw data into useful information, plan the distribution and use of results, and test the working systems in operation.

Duties may include but are not limited to the following:

- Consulting with engineering, scientific, or management personnel to define the problem
- Studying the problem and deciding the best way to solve it by using techniques such as cost accounting, sampling, and mathematical model building
- Gathering the information needed to solve the problem
- Preparing flow charts and diagrams
- Recommending the data processing equipment that is to be used and preparing instruction for programmers
- Writing up the results in a non-technical language that managers or customers can understand

Occupation Specialties

(Dot codes in parenthesis)

Electronic Data Processing Systems Analysts (012.167-066) study business procedures and problems to refine data and convert it to a form for electronic data processing.

Working Conditions

Computer systems analysts work closely with programmers, engineers, scientists, technicians, and top-level managers. They also work with clerical and non-supervisory personnel. They sometimes work as part of a team, but much of their work is done alone. They usually work in offices that are comfortable, well-lighted and air-conditioned. They may also spend time in factories, machine shops, and accounting offices analyzing equipment, procedures, methods, and work loads.

Systems analysts usually work a 5-day, 40-hour week. Evening and weekend work may sometimes be necessary to finish projects.

Out-of-town travel may be necessary for systems analysts who work as consultants.

Systems analysts may join organizations such as the Association for Systems Management, the Data Processing Management Association, or the American Federation of Information Processing Societies. Members may pay periodic fees.

Tools, Equipment and Materials used may include:

- Computer
- Peripheral Equipment
- Flow Charts
- Diagrams
- Reports
- Computer Printouts
- Plotters
- Recorders
- Digital Voltmeters
- Oscilloscopes
- Digital Displays and Readouts
- Reference Books

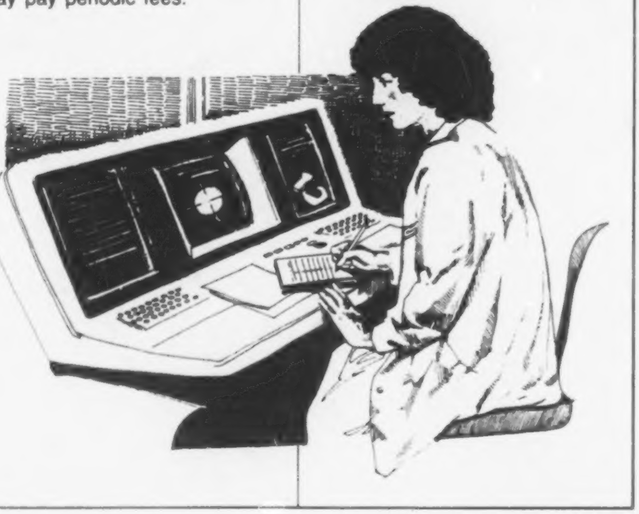
Worker Requirements

You should like:

- Activities of a scientific and technical nature
- Activities concerned with the communication of ideas

You should be able to:

- Perform a variety of duties which may change often
- Use logical step-by-step procedures to analyze and solve problems



OCCUPATION SPECIALTIES
DOT CODE:
012.167-066 Systems Analyst, Electronic Data Processing
SOC CODE: 1712

COMPUTER SYSTEMS ANALYST

- Rate information by using personal judgment or standards
- Understand the meanings of words and ideas and present information effectively
- Perform mathematical operations quickly and accurately
- Look at flat drawings or pictures and imagine how they would look as solid objects.

Physically you must:
- Maintain good health
- See and hear well, either naturally or with correction

Special Requirements:
Many employers prefer people who have had some experience in computer programming.

Opportunities for Experience:
Summer or part-time work in computer centers will give you an idea of what the job may be like. Opportunities for experience and exploration are available in all branches of the military.

Methods of Entry:
Apply directly to employers and take civil service examinations. College placement offices are of great help in getting a job. Positions may also be located by consulting newspaper want ads.

Earnings and Advancement

Earnings of systems analysts vary according to the employer, the geographic location and the analyst's experience and education.

Earnings:
Nationally, in 1987, computer systems analysts with a bachelor's degree averaged an annual salary of $32,800. Computer systems analysts with experience earned annual salaries which ranged between $25,600 and $51,300.

Computer systems analysts employed by the Federal Government averaged an annual salary of $32,700.

Fringe Benefits:
Most systems analysts receive paid vacations and holidays; life, accident, disability and hospitalization insurance; retirement plans; and sick pay. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Supervisor
- Systems Analyst
- Junior Systems Analyst
- Trainee

Employment and Outlook

There were approximately 331,000 systems analysts employed nationally in 1987. Employment of systems analysts is expected to grow much faster than the average through the year 2000 as computer capabilities are increased and computers are used to solve a greater variety of problems. College graduates with courses in programming and systems analysis and training and experience in applied fields will have the best job prospects. Persons without a college degree and college graduates unfamiliar with data processing will face competition from the large number of experienced workers seeking jobs as systems analysts.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- Technical junior or community college
- College bachelor's degree

Level(s) of education and training also available for this occupation:
- On-the-job training
- College master's degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Computer Science
- Statistics
- Accounting
- English
- Calculus
- Geometry
- Trigonometry
- Bookkeeping

More Sources of Information

- Association for Systems Management
  24587 Bagley Road
  Cleveland, OH 44138

- American Federation of Information Processing Societies
  1899 Preston White Drive
  Reston, VA 22091

- Data Processing Management Association
  505 Busse Highway
  Park Ridge, IL 60068

- Local, State, and Federal Civil Service Offices

- School Placement Offices

- Military Recruiters

STATISTICIAN

Nature of the Occupation

Statisticians collect, arrange, analyze, interpret, and present numerical data in applied or mathematical areas.

Duties may include but are not limited to the following:

- Planning methods to collect numerical data
- Developing questionnaires according to survey designs
- Conducting surveys using sampling techniques or monitoring experiments to obtain types of information desired
- Analyzing and interpreting numerical data resulting from experiments, studies, surveys, and other sources
- Adjusting and weighing raw data
- Organizing and summarizing data for analysis
- Presenting numerical information by computer readouts, graphs, charts, tables, written reports, or other materials
- Evaluating reliability of sources of data
- Describing sources of data and limitations on data usefulness

Occupation Specialties

(Dot codes in parenthesis)

Demographers (020.167-026) are applied statisticians who plan and conduct statistical studies concerning human population, including their size, growth, family structure, distribution, movement, and composition (age, sex, race, and economic status).

Vital Statisticians (020.167-026) are applied statisticians who plan registration systems for recording data on births, deaths, notifiable diseases, accidents, marriages, divorces, and annulments.

Financial Analysts (020.167-014) analyze information affecting investment programs of businesses such as banks and insurance companies.

Actuaries (020.167-010) analyze and assemble statistics to design insurance and pension plans.

Mathematical Statisticians (020.067-022) conduct research into mathematical theories and proofs that form the basis of the science of statistics and develop statistical methodology.

Statisticians may work alone or as members of a team on a particular assignment. They may supervise or be supervised by others. Statisticians generally work in clean, well-lighted, and ventilated offices except for those who occasionally conduct sample interviews in various outdoor situations.

Most statisticians work a 5-day, 40-hour week. Some overtime may be necessary to complete assignments to meet deadlines. Some statisticians may travel occasionally to supervise or set up a survey, or to gather statistical data.

Statisticians may join such associations as the American Statistical Association, the Institute of Mathematical Statistics, and the Biometrics Society.

Tools, Equipment and Materials used may include:

- Computers
- Questionnaires
- Charts, Graphs & Tables
- Calculating Machines
- Reference Books

Worker Requirements

You should like:

- Activities concerned with the communication of data
- Activities of a scientific and technical nature

You should be able to:

- Work within precise limits or standards of accuracy
- Use logical step-by-step procedures in your work
- Perform mathematical operations quickly and accurately
- Perceive details in written material or tables
- Make decisions based on judgment and verifiable information
- See differences in shapes, shadings, and measurements of figures and lines
- Understand the meanings and relationship of words and use language effectively

Physically you must:

- See well, either naturally or with correction
- Talk and hear

Special Requirements:

Many positions for statisticians require advanced degrees.

Many employers require persons applying for actuarial positions to have passed one or two of the actuarial exams given by the Society of Actuaries.

OCCUPATION SPECIALTIES

DOT CODE:

020.167-026	Statistician, Applied
020.167-026	Demographer
020.167-026	Statistician, Vital
020.067-022	Statistician, Mathematical
020.167-014	Financial Analyst
020.167-010	Actuary

SOC CODE: 1732, 1733

OKLAHOMA
CAREER
SEARCH

STATISTICIAN

Opportunities for Experience:

There are few ways to explore or gain experience as a statistician, although positions as tutors or graduate assistants may be available.

Methods of Entry:

The best methods of entry is applying directly to employers and civil service offices. Positions may be located through college placement offices and professional journals and associations.

Earnings and Advancement

Earnings depend upon the employer, geographical location, employee's experience, level of responsibility, and examinations.

Earnings:

Statisticians graduating with a bachelor's degree earned a starting salary of approximately $23,660 in 1987. Those graduating with a master's degree averaged $25,850 a year. An experienced statistician earned an average yearly salary of $39,400 in 1987. Statisticians graduating with a bachelor's degree and employed by the Federal Government earned a starting salary of $14,800 to $18,400. Those with a master's degree earned a starting salary of $22,500 to $27,200; and those with a Ph.D. earned a starting salary of $27,200 to $32,600.

The annual average salary for statisticians in the Federal Government was about $39,400.

Fringe Benefits:

Statisticians may receive paid vacations and holidays, sick leave, insurance, and retirement plans. These benefits are usually paid for, at least in part, by the employer. Those who are self-employed must provide their own benefits.

Career Ladder for this Occupation may look like this:

- Consultant
- Head of Unit
- Project Statistician
- Junior Statistician

Employment and Outlook

There were approximately 18,000 statisticians employed nationally in 1987. Employment is expected to be favorable as use of statistics expands. Persons combining knowledge of statistics with a field of application, such as engineering or physical sciences, can expect favorable job opportunities.

Related Education and Training

Level(s) of education and training usually needed for the occupation:

- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:

- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:

- College Preparatory
- Algebra
- Computer Science
- Statistics
- Accounting
- English
- Calculus
- Geometry
- Trigonometry

More Sources of Information

- American Statistical Association
  806 15th Street, NW
  Suite 640
  Washington, DC 20005

- Institute of Mathematical Statistics
  3401 Investment Boulevard
  Number 7
  Hayward, CA 94545

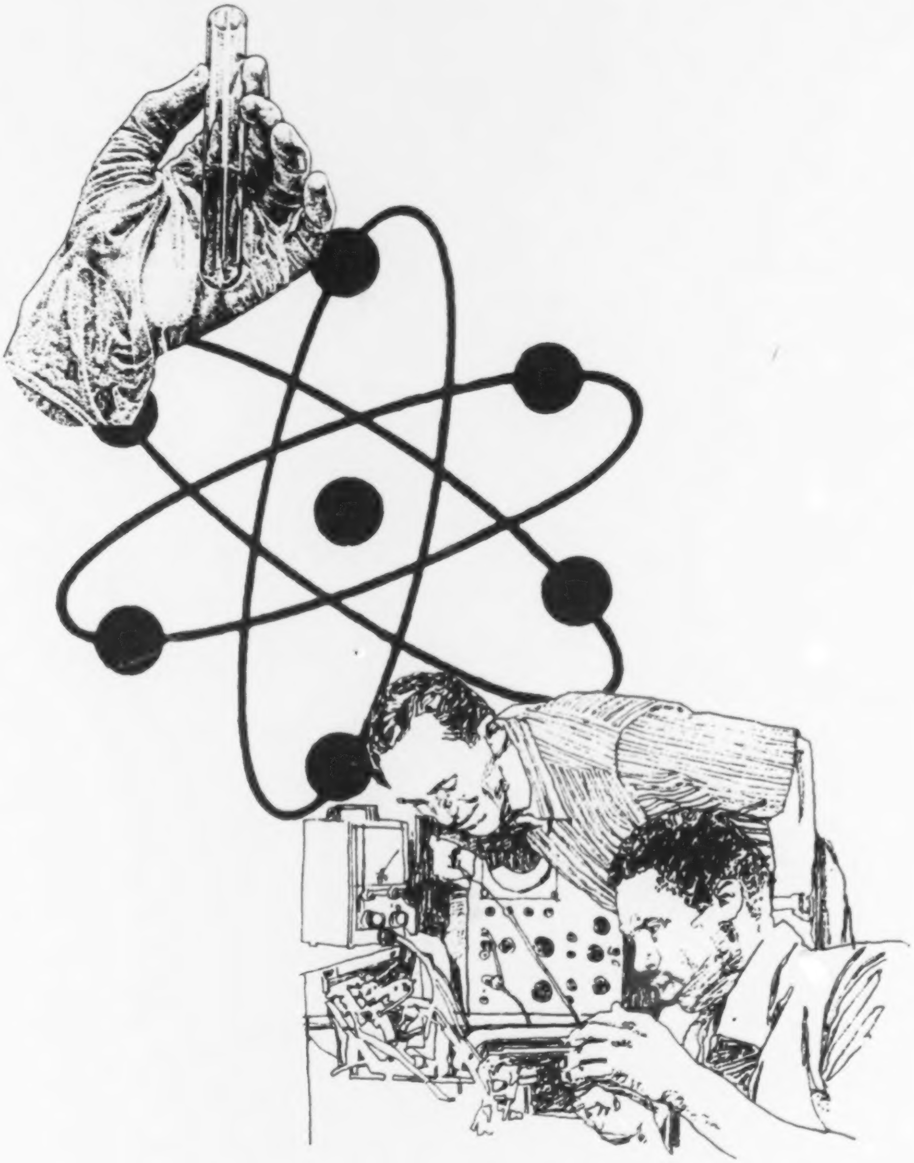
- National Council of Teachers of Mathematics
  1906 Association Drive
  Reston, VA 22091

- Society of Actuaries
  500 Park Boulevard
  Itasca, IL 60143

- Biometrics Society (ENAR)
  806 15th Street, NW
  Suite 621
  Washington, DC 20005

- Local, State, or Federal Civil Service Offices

GROUP 2: ENGINEERS



AEROSPACE ENGINEER

Nature of the Occupation

Aerospace engineers design, develop, and test aircraft, space vehicles, surface effect vehicles, missiles, and systems for use in the earth's atmosphere and outer space. They play an important role in advancing technology in commercial aviation, defense systems, and space exploration.

Duties may include but are not limited to the following:

- Designing and developing commercial, military, executive, general aviation, or special-purpose aircraft
- Designing and developing space vehicles, satellites, missiles, scientific probes, or other related hardware or systems
- Overseeing the manufacture of prototypes (models)
- Testing prototypes to evaluate their operation during actual or simulated flight conditions
- Overseeing the technical phases of air transportation

Occupation Specialties

(Dot codes in parenthesis)

Aerodynamists (002.061-010) analyze the suitability and application of designs for aircraft, missiles, and other vehicles and systems of concern to aerospace engineers. They also plan and evaluate the results of laboratory and flight-test programs.

Field Service Engineers (002.167-014) study performance reports on aircraft and recommend ways of eliminating the causes of flight and service problems in airplanes.

Stress Analysts (002.061-030) study the ability of airplanes, missiles, and components to withstand stress during flight.

Aeronautical Test Engineers (002.061-018) plan and supervise the performance testing of aerospace and aircraft products.

Aeronautical Design Engineers (002.061-022) develop basic design concepts used in the design, development, and production of aeronautical/aerospace products and systems.

Working Conditions

Aerospace engineers usually work with other engineers and scientists in modern offices. They may also spend time working in factories and on testing sites. Aerospace engineers may have to sit at drawing boards for long periods of time. They may also be subject to the noise of equipment and machinery used to test airplanes. At times, they may have to work under pressure and stress.

Aerospace engineers usually work a 5-day, 40-hour week. They may be required to work longer hours to meet deadlines. Occasionally, travel to test sites may be necessary.

Aerospace engineers may join professional organizations such as the American Institute of Aeronautics and Astronautics and the National Society of Professional Engineers. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Blueprints
- Specifications
- Preliminary Plans
- Light Tables
- Charts and Handbooks
- Measuring Scales
- Weight Scales
- Drafting Tools
- Computers

Worker Requirements

You should like:

- Activities of a scientific and technical nature
- Activities of a creative and abstract nature

You should be able to:

- Perform a variety of duties which may often change
- Think logically and use good judgment
- Work within precise limits and standards of accuracy
- Understand and use mathematics and engineering principles and methods
- Visualize three-dimensional objects from drawings or diagrams
- Compare and see differences in the size, shape, and form of lines and objects
- Understand the meanings and relationships of words and use language effectively

OCCUPATION SPECIALTIES

DOT CODE:

002.061-014	Aeronautical Engineer
002.061-010	Aerodynamist
002.061-022	Aeronautical Design Engineer
002.061-026	Aeronautical Research Engineer
002.167-014	Field Service Engineer
002.061-030	Stress Analyst
002.061-018	Aeronautical Test Engineer

SOC CODE: 1622

OKLAHOMA CAREER SEARCH

AEROSPACE ENGINEER

Physically you must:
- Have speech and hearing depending upon area of work
- See well, either naturally or with correction
- Be able to reach, handle, finger, and feel

Special Requirements:
Aerospace engineers who have primary responsibility for a project or who must sign off a contract generally are required to be licensed by the state in which they work. It is also highly desirable for those doing consultant work to be licensed.

Opportunities for Experience:
Opportunities for experience and exploration are available through work/study programs at colleges and universities and service in the United States Air Force. Summer or part-time work with research laboratories, manufacturing plants, and construction projects will provide an idea of what engineering is all about.

Methods of Entry:
Methods of entering this occupation include direct application to employers and civil service offices. Assistance in locating a job may be available through college and university placement offices.

Earnings and Advancement

Earnings depend on the individual's education, experience, field of specialization and job duties.

Earnings:
Aerospace engineers graduating with a bachelor's degree earned a starting salary of $27,780 in 1987. Experienced aerospace engineers earned salaries ranging from $27,866 to $79,021 annually. The national average income of aerospace engineers was $42,677 in 1987.

Beginning aerospace engineers with a bachelor's degree and employed by the Federal Government earned between $18,710 and $23,170 depending on scholastic records. Those with a master's degree earned a starting salary of $25,980, and those having a Ph.D. could begin at $28,039. In 1987, the average salary for engineers in the Federal Government was $38,000.

Fringe Benefits:
Depending on the employer, aerospace engineers may receive paid vacations and holidays; life, accident, disability, and hospitalization insurance; retirement plans, and sick pay. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Chief Engineer
- Aeronautical or Astronautical Engineer
- Trainee

Aerospace engineers may advance to administrative and other executive positions or become consultants.

Employment and Outlook

There were approximately 53,000 aerospace engineers employed nationally in 1987. Employment is expected to grow more slowly than the average for all occupations through the year 2000 because contracts for new military aircraft, missiles, and other aerospace systems are expected to decrease.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Geometry
- Trigonometry
- Physics
- English
- Calculus
- Statistics
- Chemistry
- Electricity & Electronics

More Sources of Information

- National Society of Professional Engineers
  1420 King Street
  Alexandria, VA 22314

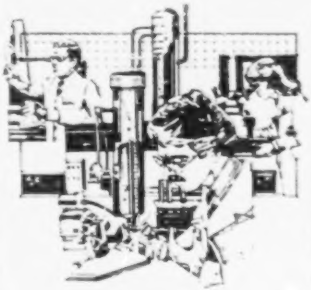
- National Aeronautic Association
  1400 I Street, NW
  Suite 550
  Washington, DC 20005

- American Institute of Aeronautics and Astronautics
  1633 Broadway
  New York, NY 10019

- College Placement Offices

- Military Recruiters

CHEMICAL ENGINEER



Nature of the Occupation

Chemical engineers design chemical plant equipment and devise processes for manufacturing chemicals and products such as gasoline, synthetic rubber, plastics, detergents, cement, paper, and pulp.

Duties may include but are not limited to the following:

- Conducting research to develop new chemical manufacturing processes
- Determining the best method for operations like mixing, crushing, heat transfer, distillation, and oxidation
- Overseeing workers controlling equipment
- Making recommendations to management concerning new manufacturing processes, location and/or design of a new plant or modification of an existing plant

Occupation Specialties

(Dot codes in parenthesis)

Chemical Engineers (008.061-018) specialize in a particular application such as research, product development or design, plant construction or operation, technical sales, or management.

Chemical Process Design Engineers (008.061-014) design equipment and devise processes to produce chemical changes in elements and compounds.

Chemical Research Engineers (008.061-022) conduct research on chemical processes and equipment to test, prove, or modify engineering theory.

Chemical Test Engineers (008.061-026) supervise and use instruments, equipment, and control devices necessary to test, record, and simplify chemical processes.

Working Conditions

Chemical engineers usually perform part of their work in modern, climate-controlled laboratories. Most chemical engineers work in manufacturing industries, primarily those producing chemicals, petroleum, and related products. Extremes in temperature, machine noise, and disagreeable odors may be experienced. Health hazards may be present because of toxic gases, fumes, dust, or liquids. Those chemical engineers working in colleges and universities usually work in a well-lighted and well-ventilated environment.

Chemical engineers work with other scientists such as chemists, metallurgists, physicists, non-professional helpers and engineering technicians.

Generally, chemical engineers work 8 hours a day, 5 days a week. They may work irregular hours when emergencies occur, when deadlines must be met, or when new processes go into effect.

Chemical engineers may join one or more professional associations such as the American Chemical Society or the American Institute of Chemical Engineers. Association members usually pay annual dues.

Tools, Equipment and Materials used may include:

- Computers
- Columns
- Drafting Tools
- Absorption & Evaporation Towers
- Slide Rules
- Stills
- Condensers

Worker Requirements

You should like:

- Solving problems of a scientific and technical nature
- Performing work which requires creativity

You should be able to:

- Work within set limits and tolerances
- Evaluate information using measurable standards
- Exercise high level judgment
- Demonstrate imagination, reliability, and patience
- Work under pressure
- Express yourself well in writing and speech

Physically you must:

- Be able to work in an atmosphere of dust and fumes
- Have good vision, either naturally or with correction
- Have good use of arms, hands and fingers

OCCUPATION SPECIALTIES

DOT CODE:

008.061-018	Chemical Engineer
008.061-014	Chemical Design Engineer, Processes
008.061-022	Chemical Research Engineer
008.061-026	Chemical Test Engineer

SOC CODE: 1626

OKLAHOMA CAREER SEARCH

CHEMICAL ENGINEER

Special Requirements:

All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health, or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensing by reciprocity.

Not all engineers need to be licensed. The exceptions are engineers working:

- For the Federal Government
- In a manufacturing corporation or a corporation engaged in interstate commerce
- In a public service corporation
- As subordinates to registered engineers.

However, the trend is toward licensing for everyone.

Opportunities for Experience:

A co-op program in college is a good way to gain experience. Because of the technical nature of the occupation, opportunities for summer employment are limited.

Methods of Entry:

Large corporations often send recruiters to college and university placement bureaus to interview students. Placement offices also maintain lists of prospective employers and job openings. Professional societies may help by advertising in magazines and by providing interviewing facilities at professional meetings.

Earnings and Advancement

Earnings of chemical engineers depend on educational background, experience, ability, and on the type, size, and location of the employing organization.

Earnings:

In 1987, chemical engineers graduating with a bachelor's degree earned an average annual salary of $27,866. Chemical engineers with a master's degree earned a starting salary averaging $33,100. Those chemical engineers graduating with a Ph.D. earned an average salary of $42,200 in 1987. Experienced chemical engineers earned an average salary of $42,677 in 1987.

Chemical engineers with a bachelor's degree employed by the Federal Government earned an average starting salary of $23,170.

Fringe Benefits:

Depending on the employer, chemical engineers receive paid vacations and holidays; life, accident, disability and hospitalization insurance; retirement plans; and sick pay. In addition, some employers offer chemical engineers the opportunity to buy stock in the company.

Career Ladder for this Occupation may look like this:

- Management or Executive Position
- Chief Engineer
- Engineer
- Junior Engineer or Assistant

The diverse training and experience of chemical engineers make them ideally suited to managerial positions.

Employment and Outlook

There were approximately 52,000 chemical engineers employed nationally in 1987. Employment is expected to grow as fast as the average for all occupations. Most job openings will result from the need to replace chemical engineers who transfer to other occupations.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:

- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:

- College Preparatory
- Algebra
- Computer Science
- Trigonometry
- Physics
- Social Studies
- Drafting
- Composition
- Calculus
- Geometry
- Chemistry
- Humanities
- Blueprint Reading

More Sources of Information

- American Institute of Chemical Engineers
  345 East 47th Street
  New York, NY 10017

- American Chemical Society
  1155 16th Street, NW
  Washington, DC 20036

- American Institute of Chemists
  7315 Wisconsin Avenue
  Bethesda, MD 20814

CIVIL ENGINEER

Nature of the Occupation

Civil engineers plan, design, and supervise the construction and maintenance of structures and facilities using new and established techniques and engineering principles.

Duties may include but are not limited to the following:

- Preparing plans and specifications
- Estimating costs and requirements of projects
- Testing materials to be used
- Determining solutions to problems
- Supervising construction and maintenance
- Inspecting existing or newly constructed projects and recommending repairs
- Performing technical research
- Determining the impact of construction on the environment

Occupation Specialties

(Dot codes in parenthesis)

Transportation Engineers (005.061-038) design and prepare plans, estimates, and specifications for the construction and operation of surface transportation projects according to state or federal construction policy.

Structural Engineers (005.061-034) plan, design, and oversee the erection of steel and other structural materials in buildings, bridges and other structures.

Hydraulic Engineers (005.061-018) design and direct the construction of power and other hydraulic engineering projects for the control and use of water.

Sanitary Engineers (005.061-030) design and oversee the construction and operation of hygienic projects.

Environmental Engineers (005.061-014) apply a knowledge of engineering by correcting or improving various areas of environmental concern, such as air, soil, or water pollution.

Working Conditions

Civil engineers may work alone or with other engineers, surveyors, or supervisors.

Civil engineers generally work 35 to 55 hours a week. They may work at construction sites or in clean, well-lighted and ventilated offices and research and testing labs.

Civil engineers may also work in remote areas of foreign countries, often moving from place to place to work on different projects.

Civil engineers may be required to furnish part of their drafting equipment.

Civil engineers may belong to an association such as American Society of Civil Engineers. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Drafting Tools and Equipment
- Blueprints and Specifications
- Handbooks
- Surveying Equipment
- Calculators
- Computers

Worker Requirements

You should like:

- Working with scientific and technical subjects
- Work requiring precise results
- Performing a variety of duties

OCCUPATION SPECIALTIES

DOT CODE:

005.061-014	Civil Engineer	005.061-018	Hydraulic Engineer
005.061-038	Transportation Engineer	005.061-030	Sanitary Engineer
005.061-034	Structural Engineer	005.061-014	Environmental Engineer

SOC CODE: 1628

OKLAHOMA
CAREER
SEARCH

CIVIL ENGINEER

You should be able to:
- Supervise others
- Accept responsibility
- Perform mathematical operations quickly and accurately
- Perform detailed and accurate work
- Make judgments based on verifiable information
- Express yourself clearly, both verbally and in writing

Physically you must:
- See well, either naturally or with correction
- Have full use of arms, legs and hands

Special Requirements:
All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health, or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensing by reciprocity.

Opportunities for Experience:
Part-time employment may be available as an engineering assistant after one or two years of college. Co-op programs in college and summer employment on construction sites provide experience.

Methods of Entry:
Methods of entering this occupation include direct application to employers and taking civil service exams. Positions may also be located by consulting local newspaper want ads, college placement offices and the state employment office.

Earnings and Advancement

Earnings depend upon the size of the employer, geographic location and employee's qualifications.

Earnings:
Civil engineers with a bachelor's degree earned a starting salary of $24,132 in 1987. Those with a master's degree averaged $33,100, and those with a Ph.D. averaged $42,200 in 1987. Civil engineers with a bachelor's degree employed by the Federal Government earned approximately $20,500 in 1987.

Fringe Benefits:
Depending on the employer, civil engineers may receive paid vacations and holidays; paid sick leave; life, accident, disability and hospitalization insurance; and retirement plans. These benefits are usually paid for, at least in part, by the employer. Civil engineers may also receive educational reimbursements, a company car, and an expense account.

Career Ladder for this Occupation may look like this:
- Researcher
- Supervisor
- Civil Engineer

Civil engineers may advance with experience or additional training or education.

Employment and Outlook

There were approximately 199,000 civil engineers employed nationally in 1987. Employment of civil engineers is expected to grow faster than the average for all occupations due to increasing demands for manufacturing plants, transportation systems, generating plants, off-shore drilling facilities, and environmental pollution control.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- Technical junior or community college

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Computer Science
- Trigonometry
- Chemistry
- Economics
- Drafting
- Composition
- Calculus
- Geometry
- Biology
- Physics
- Blueprint Reading
- Mechanical Drawing

More Sources of Information

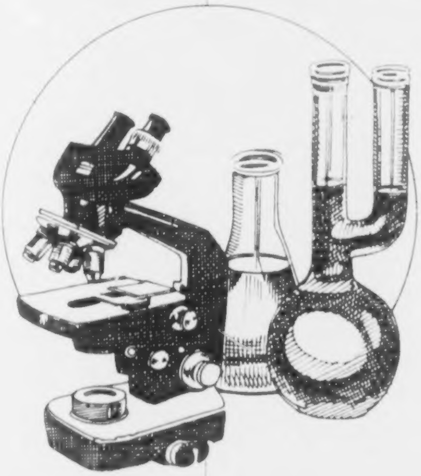
- American Society of Civil Engineers
  345 East 47th Street
  New York, NY 10017

- Society for Computer Applications in Engineering, Planning and Architecture
  15713 Crabbs Branch Way
  Rockville, MD 20855

- Accreditation Board for Engineering and Technology
  345 East 47th Street
  New York, NY 10017

- State Civil Service Commission

BIOMEDICAL ENGINEER



Nature of the Occupation

Biomedical engineers conduct research into biological aspects of humans or other animals to develop new theories and facts, or test, prove or modify known theories of life systems. They also design life support apparatus, using principles of engineering and bio-behavioral sciences.

Duties may include but are not limited to the following:
- Conducting research concerning behavioral, biological, psychological, or life systems
- Designing and developing new medical instruments and techniques, such as artificial organs, cardiac pacemakers, or ultrasonic imaging devices
- Recommending equipment design changes
- Studying engineering aspects of bio-medical systems of humans
- Assisting medical personnel in observing or treating physical aliments or deformities

Working Conditions

Biomedical engineers usually work with other engineers and technicians. They generally work as part of a research team.

Biomedical engineers usually work in well-lighted and well-ventilated offices or laboratories.

Biomedical engineers generally work a 40-hour, 5-day week. Overtime may be required during periods of research and development, or when deadlines must be met or when new procedures go into effect.

Biomedical engineers may join professional organizations such as the Biomedical Engineering Society and the Alliance for Engineering in Medicine and Biology.

Tools, Equipment and Materials used include:
- Computers
- Reference Books and Materials
- Research Material
- Engineering Tools
- Plans, Designs and Specifications
- Calculators

Worker Requirements

You should like:
- Activities that are scientific and technical in nature
- Activities dealing with things and objects
- Activities which require creativity

You should be able to:
- Think logically
- Work carefully and pay close attention to details
- Make decisions
- Communicate effectively with others
- Direct, control and plan activities
- Understand and use high levels of mathematics

Physically you must:
- Be able to work with your hands and fingers
- See well, either naturally or with correction
- Talk and hear

OCCUPATION SPECIALTIES
DOT CODE:
019.061-010 Biomedical Engineer
SOC CODE: 1639

OKLAHOMA
CAREER
SEARCH

BIOMEDICAL ENGINEER

Special requirements:
All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensure by reciprocity.

Not all engineers need to be licensed. The exceptions are engineers working: (1) for the Federal Government; (2) in a manufacturing corporation or a corporation engaged in interstate commerce; (3) in a public service corporation; and (4) as subordinates to registered engineers. However, the trend is toward licensure for everyone.

Opportunities for Experience:
A co-op program in college is a good way to gain experience. Because of the technical nature of the occupation, opportunities for summer employment are limited.

Methods of Entry:
Method of entering this occupation includes direct application to employers. Positions may also be located by consulting newspaper want ads, professional publications, college placement offices and your state employment office.

Earnings and Advancement

Earnings depend upon the type, size and location of the employing organization or corporation and the employee's education, experience, capabilities and responsibilities.

Earnings:
Biomedical engineers in manufacturing earned average yearly salaries of $50,284 in 1987. Biomedical engineers in hospitals earned up to $65,000 annually.

Beginning salaries of biomedical engineers employed by the Frederal Government earned between $18,710 and $23,170 annually.

Fringe Benefits:
Depending on the employer, biomedical engineers may receive paid vacations and holidays; life, accident, disability and hospitalization insurance; retirement plans and sick pay. These are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Chief Engineer - Manager
- Biomedical Engineer
- Biomedical Engineer Trainee

Employment and Outlook

There were approximately 4,000 biomedical engineers employed nationally in 1987. Employment for biomedical engineers is expected to grow faster than the average for all occupations, but actual numbers of openings will be small. Increased research funds could create new jobs in instrumentation and systems for delivery of health services.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- College Ph.D or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Trigonometry
- Chemistry
- English
- Geometry
- Biology

More Sources of Information

- Biomedical Engineering Society
  Box 2399
  Culver City, CA 90231

- Alliance for Engineering in Medicine and Biology
  1101 Connecticut Ave., NW
  Suite 700
  Washington, DC 20036

- State Employment Agencies

Electrical and Electronics Engineer

Nature of the Occupation

Electrical and electronics engineers conduct research and development activities in relation to the design, manufacture, testing, and application of electrical and electronic components, products, and systems.

Duties may include but are not limited to the following:

- Designing test apparatus
- Devising evaluation procedures
- Developing new and improved devices
- Recommending equipment design changes
- Writing equipment specifications
- Directing field operations
- Maintaining equipment
- Supervising workers and projects

Occupation Specialties

(Dot codes in parenthesis)

Electrical (003.061-026) and **Electronics-Research Engineers** (003.061-038) conduct research in various areas of electrical and electronic applications.

Illuminating Engineers (003.061-046) design and direct installation of illuminating equipment and systems for buildings, plants, streets, and other facilities.

Power System Electrical Engineers (003.167-018) design power system facilities and equipment and coordinate the construction, operation and, maintenance of electric power generating, receiving, and distribution stations, systems, and equipment.

Working Conditions

Electrical and electronics engineers usually work with other engineers, technicians, and construction or manufacturing workers. They may work as part of a specialist team or supervise construction or factory workers.

Electrical and electronics engineers usually work in well-lighted and ventilated offices or laboratories. Others work in factories, power installations, or out-of-doors. Electrical and electronics engineers may be required to relocate to work on different projects. Long-term projects may last two or three years.

Electrical and electronics engineers usually work 40 to 50 hours a week.

Electrical and electronics engineers may join professional organizations such as the National Society of Professional Engineers or the Institute of Electrical and Electronics Engineers. Members pay annual dues.

Worker Requirements

You should like:

- Activities that are scientific and technical in nature
- Activities dealing with things and objects
- Activities relating to processes, machines, and methods

You should be able to:

- Understand and use high-level mathematics
- Recognize differences in the size, shape and form of objects, lines, and figures
- Work carefully and pay close attention to details
- Think logically
- Analyze and solve problems based on accurate information
- Make decisions
- Direct, control, and plan activities
- Communicate effectively with others

OCCUPATION SPECIALTIES

DOT CODE:

003.061-010	Electrical Engineer
003.061-030	Electronics Engineer
003.061-026	Electrical Research Engineer
003.061-038	Electronics-Research Engineer
003.061-046	Illuminating Engineer
003.167-018	Electrical Engineer, Power System
003.061-050	Planning Engineer, Central Office Facilities

SOC CODE: 1633

OKLAHOMA
CAREER
SEARCH

Electrical and Electronics Engineer

Physically you must:
- Be able to work with your hands and fingers
- See well, either naturally or with correction, including color vision
- Talk and hear

Special Requirements:

A Ph.D. degree is required for teaching in a college or university and is usually required for research positions in industry. Electrical and electronics engineers who have primary responsibilities for a project generally are required to be licensed.

Opportunities for Experience:

Scientific and technical hobbies may provide helpful experience in this area. Summer employment in electronics businesses and co-op programs in college offer excellent opportunities for experience. Opportunities are also available through branches of the military service.

Methods of Entry:

Methods of entering this occupation include direct application to employers and civil service exams. Positions may also be located by consulting newspaper want ads, professional publications, college placement offices, and the state employment office.

Earnings and Advancement

Earnings depend upon the type, size, and location of the employing organization and the employee's education, experience, capabilities, and responsibilities.

Earnings:

In 1987, beginning electrical engineers with a bachelor's degree earned an average salary of $28,368. Those with a master's degree had beginning salaries averaging $33,100; and those with a Ph.D. degree earned salaries averaging $42,200 in 1987. Experienced electrical and electronics engineers earned an average yearly salary of $42,200.

Electrical and electronics engineers graduating with a bachelor's degree earned a starting salary between $18,710 and $23,170 with the Federal Government in 1987.

Fringe Benefits:

Depending on the employer, electrical and electronics engineers may receive paid vacations and holidays; paid sick leave; life, health, accident and disability insurance; and retirement plans. These benefits are usually paid for, at least in part, by the employer. Some employers may also provide educational reimbursements.

Career Ladder for this Occupation may look like this:
- Chief Engineer - Manager
- Electrical and Electronics Engineer
- Electrical and Electronics Engineer Trainee

Employment and Outlook

There were approximately 401,000 electrical and electronics engineers employed nationally in 1987. Employment is expected to increase much faster than the average through the year 2000 due to the growing demand for computers, communications equipment, military electronics, and electrical and electronic consumer goods.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- Ph.D. degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- English
- Calculus
- Trigonometry
- Physics
- Cooperative Education-Trade & Industrial
- Electricity & Electronics
- Composition
- Algebra
- Geometry
- Chemistry
- Humanities
- Drafting
- Machine Shop

More Sources of Information

- National Engineering Consortium
  505 N. Lake Shore Drive
  Suite 4808
  Chicago, IL 60611

- Institute of Electrical and Electronics Engineers
  345 East 47th Street
  New York, NY 10017

- National Society of Professional Engineers
  1420 King Street
  Alexandria, VA 22314

- Federal, State, and Local Civil Service Offices

- State Employment Offices

INDUSTRIAL ENGINEER

Nature of the Occupation

Industrial engineers design, improve, and install combined systems of machines, equipment, energy, and workers for maximum productivity.

Duties may include but are not limited to the following:
- Studying data to determine the functions and responsibilities of workers and work units
- Establishing work measurement programs and making observations to determine the best use of equipment and workers
- Developing programs to simplify work flow, work count, economy of worker motions, and layout of units
- Planning and overseeing plant safety and accident prevention programs
- Planning and overseeing job study and training programs
- Training industrial engineering technicians and other personnel

Occupation Specialties

(Dot codes in parenthesis)

Time-Study Engineers (012.167-070) develop work measurement procedures and direct time-and-motion and incentive studies to promote the efficient use of employees and facilities. They may also develop recommendations affecting work methods and budget decisions.

Safety Engineers (012.061-014) examine plans and specifications of new machinery and inspect existing machinery and work areas to insure safety standards are being met.

Manufacturing Engineers (012.167-042) determine space requirements, plan or improve production methods, estimate production times and the best use of personnel for production schedules, and direct and coordinate manufacturing processes in industrial plants.

Quality-Control Engineers (012.167-054) plan and direct the development, application, and maintenance of quality standards for processing materials into partially-finished or finished products.

Working Conditions

Industrial engineers usually work with others as part of a team. They may also supervise other engineers or technicians. Industrial engineers may work in well-lighted and air-conditioned offices or in production areas where they may be exposed to fumes, noise, extreme temperatures, dust, and other plant conditions.

Industrial engineers usually work a 5-day, 40-hour week. Overtime may be required to complete a particular job. Industrial engineers employed by consulting firms may travel extensively.

Industrial engineers may join professional organizations such as the Institute of Industrial Engineers. Members usually pay periodic dues.

Tools, Equipment and Materials used may include:
- Blueprints
- Specifications
- Charts
- Drafting Tools
- Stopwatches
- Plans
- Handbooks
- Computers
- Measuring Devices

Worker Requirements

You should like:
- Activities of a scientific and technical nature
- Activities involving machines, techniques, and people
- Activities which require creativity

You should be able to:
- Work within precise limits or standards of accuracy
- Perform a variety of duties which change often
- Think logically
- Perform mathematical calculations quickly and accurately

OCCUPATION SPECIALTIES

DOT CODE:

012.167-030 Industrial Engineer
012.167-070 Time-Study Engineer
012.061-014 Safety Engineer
012.167-042 Manufacturing Engineer
012.167-054 Quality-Control Engineer

SOC CODE: 1634

OKLAHOMA
CAREER
SEARCH

INDUSTRIAL ENGINEER

- Present your ideas effectively in speech and writing
- Observe details in objects or drawings and recognize slight differences in shapes or shadings
- Visualize flat drawings or pictures as solid objects
- Direct and plan activities

Physically you must:
- See well, either naturally or with correction

Special Requirements:

All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health, or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensing by reciprocity.

Not all engineers need to be licensed. The exceptions are engineers working: (1) for the Federal Government, (2) in a manufacturing or interstate commerce corporation, (3) in a public service corporation, and (4) as subordinates to registered engineers. However, the trend is toward licensing for everyone.

Opportunities for Experience:

Summer or part-time work with research laboratories, manufacturing plants, and construction projects offer opportunities for experience.

Methods of Entry:

Methods of entering the occupation include applying directly to employers and taking civil service exams. Positions may also be located by consulting newspaper want ads, professional journals, and college placement offices.

Earnings and Advancement

Earnings depend upon the employer and employee's experience and education.

Earnings:

Nationally, in 1987, industrial engineers graduating with a bachelor's degree earned a starting salary of $27,048. Those with a master's degree earned a starting salary of $33,100 in 1987. Industrial engineers with experience earned salaries averaging $42,200.

Industrial engineers with a bachelor's degree earned starting salaries ranging from $18,710 to $23,170 with the Federal Government in 1987.

Fringe Benefits:

Depending on the employer, industrial engineers may receive paid vacations and holidays; life and hospitalization insurance; retirement plans; and paid sick leave. Many employers will also pay expenses for additional education.

Career Ladder for this Occupation may look like this:
- Supervisor
- Industrial Engineer
- Trainee

Industrial engineers may advance through experience, supervisory ability, and additional education.

Employment and Outlook

There were an estimated 117,000 industrial engineers employed nationally in 1987. Employment of industrial engineers is expected to grow faster than the average for all occupations through the year 2000 due to increasing industrial growth, increasing complexity of industrial operations, and greater emphasis on scientific management and safety engineering. Jobs will also be created as firms seek to reduce costs and increase productivity through scientific management and safety engineering.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- Technical junior or community college
- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Geometry
- Trigonometry
- English
- Calculus
- Statistics
- Chemistry
- Physics
- Blueprint Reading
- Machine Shop
- Shop Mechanics
- Composition
- Physical Science
- Humanities
- Drafting
- Mechanical Drawing

More Sources of Information

- American Society of Safety Engineers
  1800 East Oakton
  Des Plaines, IL 60018

- American Society for Quality Control
  310 W. Wisconsin Avenue
  Milwaukee, WI 53203

- Society of Manufacturing Engineers
  One SME Drive
  Box 930
  Dearborn, MI 48121

MECHANICAL ENGINEER

Nature of the Occupation

Mechanical engineers plan and design machines, tools, engines, and other equipment which produce or use power.

Duties may include but are not limited to the following:
- Designing products or systems
- Planning and directing engineering personnel in the fabrication of test control apparatus and equipment
- Developing methods and procedures for testing products or systems
- Directing and coordinating construction and installation activities
- Coordinating operation, maintenance, and repair activities to obtain the best use of machines and systems
- Evaluating field installations and recommending design changes to eliminate malfunctions

Occupation Specialties

(Dot codes in parenthesis)

Automotive Engineers (007.061-010) develop new or improved designs for automobile structural parts, engines, transmissions, suspension systems, and associated equipment. They may also direct the building, modification, and testing of vehicles.

Utilization Engineers (007.061-034) solve engineering problems concerned with industrial utilization of gas as a source of power.

Plant Engineers (007.167-014) direct and coordinate activities relating to the design, construction, and maintenance of equipment and machinery in an industrial plant.

Working Conditions

Mechanical engineers usually work with other engineers, managers, shop employees, construction workers, and drafters. They work at desks or drafting tables in well-lighted, climate-controlled offices. Mechanical engineers working in maintenance, production, construction, or installation activities generally work in plants or outdoors and are exposed to plant or weather conditions.

Mechanical engineers generally work a 5-day, 40-hour week. Overtime may be required in case of emergencies or to meet deadlines. Mechanical engineers working in production or maintenance may work on weekends and be on call at other times.

Mechanical engineers may join professional organizations such as the American Society of Mechanical Engineers and the National Society of Professional Engineers. Members usually pay dues.

Tools, Equipment and Materials used may include:
- Cars, Trucks & Buses
- Engines, Transmissions & Other Auto Equipment
- Instruments & Controls
- Transfer Systems
- Plans, Designs & Specifications
- Reference Books
- Calculators
- Computers
- Engineering Tools

Worker Requirements

You should like:
- Activities of a scientific and technical nature
- Activities involved with machines and mechanical devices
- Activities which require creativity

You should be able to:
- Work within precise limits or standards of accuracy
- Reason clearly and logically
- Perform arithmetical operations quickly and accurately
- Visualize flat drawings and pictures as solid objects
- Recognize detail in objects or drawings and slight differences in shapes and shadings
- Rate information by using personal judgment or measurable standards
- Plan, direct, and control activities

Physically you must:
- See well, either naturally or with correction
- Use your arms, hands, and fingers well

Special Requirements:

All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health, or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensing by reciprocity.

Not all engineers need to be licensed. The exceptions are engineers working: (1) for the Federal Government, (2) in a manufacturing or interstate

OCCUPATION SPECIALTIES

DOT CODE:

007.061-014	Mechanical Engineer
007.061-010	Automotive Engineer
007.061-034	Utilization Engineer
007.167-014	Plant Engineer

SOC CODE: 1635

OKLAHOMA
CAREER
SEARCH

MECHANICAL ENGINEER

commerce corporation, (3) in a public service corporation, and (4) as subordinates to registered engineers. However, the trend is toward licensing for everyone.

Opportunities for Experience:
Opportunities for experience include summer and/or part-time work with manufacturing firms.

Methods of Entry:
Methods of entering this occupation include direct application to employers and taking civil service exams. Positions may also be located by consulting newspaper want ads, college placement offices, and state employment offices.

Earnings and Advancement

Earnings depend upon the type, size, and location of the employer and the engineer's education, experience, capabilities, and job responsibilities.

Earnings:
Nationally, in 1987, mechanical engineers with experience earned annual incomes ranging from $27,866 to $79,021, with a national average of $42,677. Mechanical engineers graduating with a bachelor's degree earned an average yearly starting salary of approximately $27,864 in 1987. Those with a master's degree earned an average yearly salary of about $33,100 and Ph.D.'s earned an average salary of $42,200 annually.

Fringe Benefits:
Depending on the employer, mechanical engineers may receive paid vacations and holidays; sick leave; group health and life insurance; pension plans; and reimbursement for further education. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Senior Engineer/or Supervisor
- Mechanical Engineer
- Engineering Trainee

Engineers usually advance to positions of greater responsibility after gaining experience.

Employment and Outlook

There were approximately 233,000 mechanical engineers employed nationally in 1987. Employment of mechanical engineers is expected to increase much faster than the average for all occupations through the year 2000 as the demand for machinery and machine tools grows and industrial machinery and processes become increasingly complex. Despite this expected employment growth, however, most job openings will result from the need to replace mechanical engineers who transfer to other occupations or leave the labor force for other reasons.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Computer Science
- Trigonometry
- Physical Science
- Humanities
- Drafting
- Machine Shop
- Metal Shop
- English
- Calculus
- Geometry
- Chemistry
- Physics
- Blueprint Reading
- Electricity & Electronics
- Mechanical Drawing

More Sources of Information

- American Society of Mechanical Engineers
  345 East 47th Street
  New York, NY 10017

- The American Academy of Mechanics
  c/o Civil Engineering Department
  Northwestern University
  Evanston, IL 60201

- National Society of Professional Engineers
  1420 King Street
  Alexandria, VA 22314

- College Placement Offices

NUCLEAR ENGINEER

Nature of the Occupation

Nuclear engineers participate in broad areas of analysis, design, management, and/or research using nuclear energy for power plants, transportation, space exploration, diagnostic health, and environmental control of pollution.

Duties may include but are not limited to the following:
- Conducting research into problems of nuclear energy
- Designing and developing nuclear equipment
- Monitoring the testing, operation, and maintenance of nuclear reactors
- Evaluating findings to develop new uses of radioactive processes
- Preparing technical reports

Occupation Specialties

(Dot codes in parenthesis)

Nuclear Equipment Design Engineers (015.061-010) design nuclear machinery and equipment.

Nuclear Equipment Research Engineers (015.061-018) conduct tests on nuclear machinery and equipment.

Nuclear Equipment Test Engineers (015.061-022) conduct tests on nuclear machinery and equipment.

Working Conditions

Nuclear engineers usually work with others as part of an engineering team. Depending on the particular position, they may supervise other engineers, technicians, and other workers.

Nuclear engineers may work in comfortable offices and research laboratories. They generally work a 5-day, 40-hour week. Overtime may be required in case of emergencies or to meet deadlines.

Nuclear engineers may join professional organizations such as the American Nuclear Society or the National Society of Professional Engineers. Members usually pay dues.

Tools, Equipment and Materials used may include:
- Plans, Designs & Specifications
- Calculators
- Computers
- Engineering Reports

Worker Requirements

You should like:
- Activities of a scientific and technical nature

You should be able to:
- Work within precise limits or standards of accuracy
- Reason clearly and logically
- Perform mathematical operations quickly and accurately
- Visualize objects from diagrams
- Rate information by using personal judgment or measurable standards

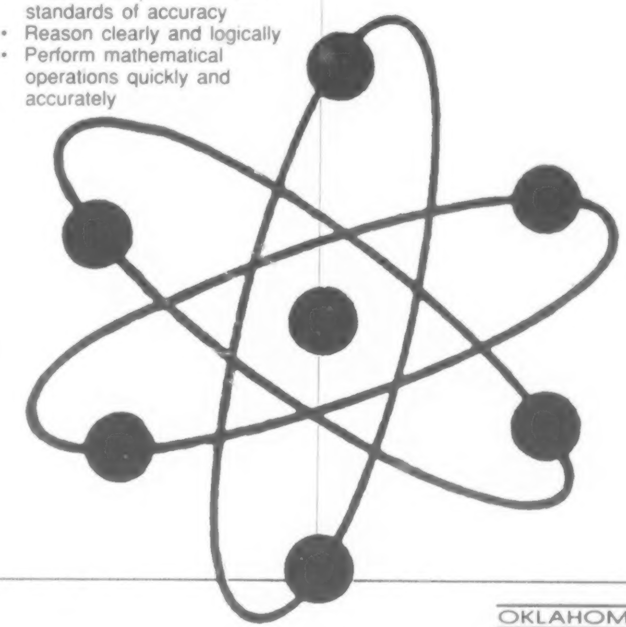
Physically you must:
- See well, either naturally or with correction

Special Requirements:

All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health, or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensing by reciprocity.

Opportunities for Experience:

There are no viable work opportunities at the present.



OCCUPATION SPECIALTIES

DOT CODE:

015.061-014	Nuclear Engineer
015.061-010	Design Engineer, Nuclear Equipment
015.061-018	Research Engineer, Nuclear Equipment
015.061-022	Test Engineer, Nuclear Equipment

SOC CODE: 1627

OKLAHOMA
CAREER
SEARCH

NUCLEAR ENGINEER

Methods of Entry:

Methods of entering this occupation include direct application to employers and civil service offices. Assistance in locating a job may also be available from professional associations, college and university placement offices, and state employment offices.

Earnings and Advancement

Earnings depend upon the employer and the education, experience capabilities, and job responsibilities of the employee.

Earnings:

Nuclear engineers with a bachelor's degree earned a starting salary of $27,696 in 1987. Engineers with a master's degree started at $33,100 and those with a Ph.D. at $42,200 in 1987. The average salary for engineers in the Federal Government was $38,000 in 1987.

Fringe Benefits:

Depending on the employer, nuclear engineers may receive paid vacations and holidays; sick leave; group health and life insurance; pension plans; and reimbursement for further education. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:

- Chief Engineer and Supervisor
- Nuclear Engineer
- Engineering Trainee

Engineers usually advance to positions of greater responsibility after gaining experience.

Employment and Outlook

There were approximately 14,000 nuclear engineers employed nationally in 1987. Almost one-fifth were in the Federal Government. Engineers in the private sector worked for public utilities or engineering consulting firms. Employment of nuclear engineers is expected to change little through the year 2000.

Related Education and Training

Levels(s) of education and training usually needed for this occupation:

- College bachelor's degree
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:

- College Preparatory
- Algebra
- Computer Science
- Chemistry
- Blueprint Reading
- English
- Calculus
- General Math
- Physics

More Sources of Information

- American Nuclear Society
  555 North Kensington Avenue
  La Grange Park IL 60525

- Atomic Industrial Forum, Inc.
  Public Affairs and Information Program
  7101 Wisconsin Avenue
  Washington, DC 20014

- National Society of Professional Engineers
  1420 King Street
  Alexandria, VA 22314

PETROLEUM ENGINEER

Nature of the Occupation

Most petroleum engineers explore and drill for oil and gas, and many plan and supervise drilling operations, extraction, storage, initial treatment, and transportation. Their goal is the most profitable recovery of oil and gas by the most efficient methods of production. They must develop enhanced recovery methods to increase the proportion of oil it is possible to recover from reservoirs.

Duties may include but are not limited to the following:

- Study maps of subsurface oil and gas reservoirs and analyze recommendations of engineering specialists to plan the location of wells
- Evaluate probable well production rate and the economic value of gas and oil properties
- Recommend processes to enhance the recovery of oil and gas
- Develop well-drilling plans including drilling time, directional drilling and testing, and material requirements and costs
- Consult during drilling operations to resolve such problems as bore directional change, unsatisfactory drilling rate, or water in well bore
- Advise substitution of drilling mud compounds or tool bits to improve drilling
- Inspect wells to ensure that casing and tubing installations are complete
- Plan for the reception, removal of contaminants, and separation of oil and gas products
- Monitor the production rate of wells and keep production records
- Correct well production by repacking well bores
- Apply knowledge of petroleum engineering to solve environmental and safety problems
- Design pumping equipment, pipelines, and gas-oil separators

Occupation Specialties

(Dot codes in parenthesis)

Mining and Oilfield Equipment Design Engineers (010.061-010) design mining and oil well equipment.

Mining and Oil Well Equipment Research Engineers (010.061-022) conduct research to develop improved mining and oil well equipment.

Mining and Oilfield Equipment Test Engineers (010.061-030) test mining and oilfield machinery and equipment.

Mud Analysis Well-Logging Captains (010.131-010) supervise and coordinate workers who analyze oil well drilling mud and well cuttings to detect presence of oil and gas and to identify productive strata.

Chief Research Engineers (010-161-010) coordinate research to develop improved methods of drilling wells and producing oil and gas.

Chief Petroleum Engineers (010.161-014) plan and direct engineering activities of petroleum companies.

Chief Engineers (010.167-010) direct workers in engineering departments of petroleum production or pipeline companies and advise management on engineering problems.

Mud-Analysis Well Logging District Supervisors (010.167-014) plan and direct mud-sample testing operations.

Oil-Well Services Superintendents (010.167-018) direct technical service activities to solve drilling and production problems.

Working Conditions

Petroleum engineers usually work with others as part of an engineering team. Depending on the particular position, they may supervise other engineers, technicians, clerks, or other workers. Working conditions vary considerably. Those engaged in consulting, design, or research spend much time in offices and laboratories which are comfortable, modern, and well-equipped. Petroleum engineers working in oil fields or on offshore rigs must work outdoors in all types of weather. Work at well sites may be strenuous and dirty. In the field, petroleum engineers must practice strict safety and fire prevention techniques and wear protective clothing.

Working hours for petroleum engineers depend on the kind of work being done. Those working in offices or laboratories usually work a 5-day, 40-hour week.

Tools, Equipment and Materials used may include:

- Computers & Computerized Monitoring Equipment
- Acids, Solvents, Polymers & Other Special Chemicals
- Engineering Reports, Charts & Logs
- Fire & Other Safety Equipment
- Drilling Rigs, Compressors, Well Heads & Valves

OCCUPATION SPECIALTIES

010.061-010	Mining and Oilfield Equipment Design Engineer
010.061-018	Petroleum Engineer
010.061-022	Mining and Oil Well Equipment Research Engineer
010.061-030	Mining and Oilfield Equipment Test Engineer
010.131-010	Mud Analysis Well-Logging Captain
010.061-010	Chief Research Engineer
010.161-014	Chief Petroleum Engineer
010.167-010	Chief Engineer
010.167-014	Mud-Analysis Well District Supervisor
010.167-018	Oil-Well Services Superintendent

OKLAHOMA
CAREER
SEARCH

PETROLEUM ENGINEER

Worker Requirements

You should like:

- Activities involving the communication of data
- Activities of a scientific and technical nature
- Activities involving machines, processes, and techniques
- Activities involving things and objects
- Creative thinking

You should be able to:

- Reason logically and use logical step-by-step procedures in your work
- Understand the meanings of words and present information effectively
- Perform mathematical operations quickly and accurately
- Visualize three-dimensional objects from diagrams
- See detail in objects or drawings and recognize differences in shapes or shadings
- Direct and plan an entire activity or the activities of others
- Make decisions using personal judgment or verifiable data
- Have agreeable working relationships with others
- Perform work within precise standards of accuracy

Physically you must:

- Use your arms, hands, and, fingers fully
- Speak, see and hear, either naturally or with correction

Special Requirements:

In some states, engineers who provide professional services affecting health, life, or property must be licensed by the Board of Registration for Professional Engineers. To become a licensed professional engineer, you must have a bachelor's degree in an approved engineering program and four years of additional experience. Up to two years of the experience requirement may be fulfilled by obtaining advanced degrees, with one year of credit granted for a master's degree and one year for a Ph.D. In addition, you must pass a two-part, 16-hour examination and submit professional and character references.

Opportunities for Experience:

Summer or part-time jobs with a petroleum company may permit students to observe petroleum engineers at work and experience the working conditions. High school students may join the Junior Engineering Technical Society or participate in summer programs such as the Minority Introduction to Engineering.

Earnings and Advancement

Starting salaries for engineers with bachelor's degrees are significantly higher than the starting salaries of college graduates in other fields. Earnings of petroleum engineers depend on their education and experience; level of responsibility; and the type, size, and geographic location of the employer. For example, petroleum engineers working in locations such as Alaska or the Middle East receive significantly higher salaries than do those employed in most other areas. Petroleum engineering is the highest paid engineering specialty.

Earnings:

Starting offers for those with a bachelor's degree in petroleum engineering averaged $33,000 in 1987, with a range between $27,600 and $35,100. Depending on their college records, minimum starting salaries of petroleum engineers employed by the Federal Government in 1987 were $17,383 or $21,527 with a bachelor's degree, $21,527 or $26,331 with a master's degree, and $30,640 or $34,839 with a Ph.D.

Career Ladder for this Occupation may look like this:

- Chief Engineer or Supervisor
- Petroleum Engineer
- Engineering Trainee

Employment and Outlook

Petroleum engineers held almost 22,000 jobs in 1987, mostly in the petroleum industry and allied fields. Employers include major oil companies; small, independent oil exploration, production, and service companies; engineering consulting firms; government agencies; and oil field service and equipment suppliers. Some work as independent consultants. Most petroleum engineers work in Texas, Oklahoma, Louisiana, and California, as well as overseas in petroleum-producing countries.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:

- College bachelor's degree
- College master's degree

School subjects helpful in preparing for this occupation include:

- College Preparatory

More Sources of Information

- Minority Intro. to Engineering
  c/o Accreditation Board for
  Engineering and Technology
  345 East 47th Street
  New York, NY 10017

Metallurgical & Materials Engineer

Nature of the Occupation

Metallurgical engineers extract, process, and convert metals into useful finished products.

Duties may include but are not limited to the following:

- Conducting research and development
- Developing processing methods plants
- Supervising production processes
- Selling and servicing metal products

Occupation Specialties

(Dot codes in parenthesis)

Extractive Metallurgists (011.061-018) extract metals from ores through processes such as smelting or refining, develop uses for scrap metal and low grade ores, control temperature, and charge mixtures furnaces.

Physical Metallurgists (011.061-022) study the structure of metals in order to develop new alloys, new uses for metals through alloying and ways to produce them commercially.

Metallographers (011.061-014) conduct tests on metals and alloys for developing new and improved metals and alloys and improve production methods.

Foundry Metallurgists (011.061-010) conduct research to develop and improve sand molding, melting, alloying, and metal pouring methods.

Welding Engineers (011.061-026) specialize in the development and application of welding equipment and welding techniques for hard-to-weld metal alloys and assemblies.

Materials Engineers (019.061-014) evaluate technical and economic factors toward the recommendation of engineering and manufacturing strategies to attain design objectives of products and processes by applying their knowledge of material science and related technologies.

Working Conditions

Metallurgical and materials engineers may work alone or with other members of an engineering team under the general supervision of a chief engineer. They may supervise the work of technicians or other workers.

Metallurgical and materials engineers generally work in offices and laboratories that are well-lighted and ventilated. Some may work in mills, mines, or plants.

Metallurgical and materials engineers usually work a 40-hour week. Overtime may be required to complete projects. Traveling may also be required.

Metallurgical and materials engineers may join organizations such as the American Institute of Mining, Metallurgical, and Petroleum Engineers and the American Society for Metals. Members usually pay periodic dues.

Tools, Equipment and Materials used may include:

- Photographic Equipment
- Microscopes & Metallographs
- Melting, Welding & Extrusion Equipment
- Machinery for Forming Metals
- Heat-Treating Furnaces
- Electron Microscopes & Microprobes
- Mechanical Testing Equipment
- Computers

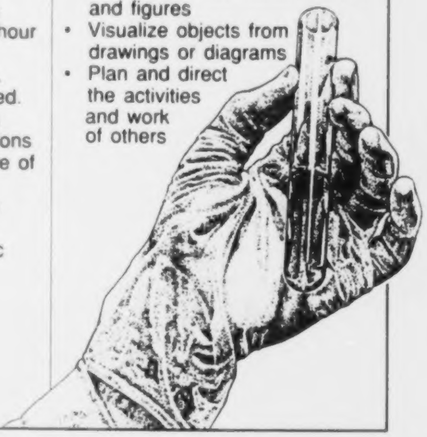
Worker Requirements

You should like:

- Activities dealing with things and objects
- Activities of a scientific and technical nature
- Activities of an abstract and creative nature

You should be able to:

- Use logical step-by-step procedures to complete tasks
- Work within set limits or standards
- Follow detailed instructions
- Understand mathematics and concepts
- Recognize differences in the size, shape, and form of lines and figures
- Visualize objects from drawings or diagrams
- Plan and direct the activities and work of others



OCCUPATION SPECIALTIES

DOT CODE:

011.061-018	Extractive Metallurgist	011.061-010	Foundry Metallurgist
011.061-022	Physical Metallurgist	011.061-026	Welding Engineer
011.061-014	Metallographer	019.061-014	Materials Engineer

SOC CODE: 1623

OKLAHOMA CAREER SEARCH

Metallurgical & Materials Engineer

Physically you must:
- See well, either naturally or with correction
- Be able to reach, handle, and finger objects and materials

Special Requirements:
All fifty states and the District of Columbia have licensing regulations for engineers whose work affects life, health, or property. Each state administers its own examination. All states now have legal provisions to grant engineering licensing by reciprocity.

Not all engineers need to be licensed. The exceptions are engineers working: (1) for the Federal Government, (2) in a manufacturing or interstate commerce corporation, (3) in a public service corporation, and (4) as subordinates to registered engineers. However, the trend is toward licensing for everyone.

Opportunities for Experience:
Co-op programs in colleges and universities and summer job programs in industry provide experience for this occupation.

Methods of Entry:
Methods of entering this occupation include direct application to employers and taking civil service examinations. Positions may also be located by consulting newspaper want ads and professional publications, school placement offices, and state employment offices.

Earnings and Advancement

Earnings depend upon the employer and the employee's education, experience, and specialty.

Earnings:
Nationally, in 1987, metallurgical and materials engineers with experience earned salaries ranging from $28,885 to $80,320, with an average salary of $43,200. Metallurgical engineers graduating with a bachelor's degree earned a starting salary of $27,990 in 1987. Those with a master's degree earned a starting salary of $33,100, and Ph.D.'s earned a starting salary of $42,200.

Fringe Benefits:
Depending on the employer, metallurgical engineers may receive paid vacations and holidays; life and hospitalization insurance; and paid sick leave. These are paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Chief Metallurgical Engineer
- Metallurgical Supervisor
- Metallurgical Engineer
- Engineering Trainee

Metallurgical and materials engineers may advance through experience and/or additional education. For teaching positions in colleges and universities a Ph.D. degree is usually required. About half of all metallurgical engineers employed in research and development work have a Ph.D.

Employment and Outlook

There were approximately 18,000 metallurgical and materials engineers employed nationally in 1987. Employment is expected to grow faster than the average for all occupations because of the need to develop new metals and alloys, adapt current ones to new needs, improve ways of recycling solid waste, and processing low-grade ores. Metallurgical engineers will also be needed to solve problems associated with the efficient use of nuclear energy. Most job openings, however, will result from the need to replace metallurgical engineers who retire or transfer to other occupations.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- College Ph.D. or professional degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Algebra
- Computer Science
- Trigonometry
- Earth Science
- Physics
- Metal Shop
- Welding
- English
- Calculus
- Geometry
- Chemistry
- Physical Science
- Machine Shop
- Shop Math

More Sources of Information

- American Institute of Mining, Metallurgical, and Petroleum Engineers
  345 East 47th Street
  14th Floor
  New York, NY 10017
- American Society of Certified Engineering Technicians
  P. O. Box 7789
  Shawnee Mission, KS 66207
- The Metallurgical Society
  420 Commonwealth Drive
  Warrendale, PA 15086
- American Society for Metals
  Metals Park, OH 44073
- Military Recruiters

ARCHITECT

Nature of the Occupation

Architects plan, design, and supervise the construction of all types of buildings, such as private homes, offices, theaters, libraries, museums, and factories.

Duties may include but are not limited to the following:

- Consulting with clients to determine style, budget constraints, expected use of the building, proposed location, and special requirements
- Referring to building codes and zoning laws
- Working with drafters to prepare drawings for the client
- Developing detailed drawings and models
- Presenting designs to the client for approval
- Translating the design into construction documents
- Selecting a builder or contractor
- Supervising the construction of the building
- Approving any changes or substitutions of building materials

Occupation Specialties

(Dot codes in parenthesis)

Architects (001.061-010) may specialize in a particular area such as a project manager, designer, drafter, specifications writer, or cost estimator. Architects may also specialize in the design of certain types of buildings.

Working Conditions

Although some architects have individual practices and work alone, the majority of architects work as members of a team under the direction of a project manager or a more experienced architect. The team may include not only architects but many other professional persons.

Architects generally work in clean, well-lighted and well-ventilated offices and many spend long hours at the drawing board. Some of their time is spent outdoors inspecting proposed building sites or overseeing construction.

Architects usually work 40 hours a week. Self-employed architects often work long hours, especially during busy periods. They may work under great stress to meet deadlines. Architects may often travel to a client's office or building sites.

Architects may have to furnish some or all of their drafting tools as well as their own transportation.

Architects may belong to professional associations such as the American Institute of Architects and the Society of American Registered Architects. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Drawing Tools
- Parallels
- Scales
- Structural, Mechanical & Product Handbooks
- Cameras
- Model Makers
- Drawing Boards or Tables
- Calculators
- Miscellaneous Printed Material

Worker Requirements

You should like:

- Activities of a scientific or technical nature
- Activities which require a creative imagination

You should be able to:

- Perform a variety of duties which may often change
- Work within precise limits or standards of accuracy
- Rate information according to measurable standards
- Visualize flat drawings or pictures as solid objects
- Perform arithmetic operations quickly and accurately
- Reason logically and present information effectively
- Plan, direct, and control an entire activity or the activities of others

Physically you must:

- Use your hands and fingers to draw and make models
- See well, either naturally or with correction

Special Requirements:

All states require passing a licensing exam before practicing architecture. Prerequisites for the exam include a bachelor's or master's of architecture from an accredited program in architecture certified by the

OCCUPATION SPECIALTIES
DOT CODE:
001.061-010 Architect
SOC CODE: 161

OKLAHOMA
CAREER
SEARCH

ARCHITECT

National Architectural Accrediting Board (NAAB) and followed by a 3-year practical training requirement, one year of which must be employment in the office of a registered architect. Some states also require a qualifying exam as a prerequisite to the registration examination. Reciprocity agreements between states are among the best in all professions.

Opportunities for Experience:
Practical experience is part of the course of study in a school of architecture, although summer jobs in drafting or construction may be available and are certainly helpful.

Methods of Entry:
Methods of entering this occupation include direct application to employers and taking civil service exams. Positions may also be located through college placement offices and professional journals.

Earnings and Advancement

Salaries vary according to the type of firm and its geographic location. Architects with well-established private practices generally earn more than highly paid salaried employees in architectural firms. Architects starting their own practices may go through a period when their expenses are greater than their income.

Earnings:
Newly hired architects receive approximately $21,000 annually and their salaries increase as they work toward passing the registration examination. Experienced architects earned salaries ranging from $30,000 to $40,000 in 1987, the average income being $30,000 annually.

In 1987, the average salary for experienced architects working in the Federal Government was approximately $36,500.

Fringe Benefits:
Depending on the employer, architects may receive paid vacations and holidays; life, accident and hospitalization insurance; retirement plans and sick pay. These benefits are usually paid for, at least in part, by the employers.

Career Ladder for this Occupation may look like this:
- Principal or Senior Partner
- Partner
- Project Manager
- Architect
- Drafter

Architects may advance through experience, further training and education, and handling complex assignments.

Employment and Outlook

There were approximately 84,000 architects employed nationally in 1987. Employment is expected to rise faster than the average for all occupations through the year 2000. Employment is not expected to be affected by computer technology, but it is affected by the cyclical changes in the economy. During recessions, architects will face keen competition for job openings. Competition will continue to be keen for jobs in the most prestigious firms which offer good potential for career advancement.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree
- College master's degree

Level(s) of education and training also available for this occupation:
- Technical junior or community college

School subjects helpful in preparing for this occupation include:
- College Preparatory
- English
- Algebra
- Geometry
- Physics
- Trigonometry
- Blueprint Reading
- Graphic Arts
- Mechanical Drawing
- Arts
- History
- Drafting
- Industrial Arts

More Sources of Information

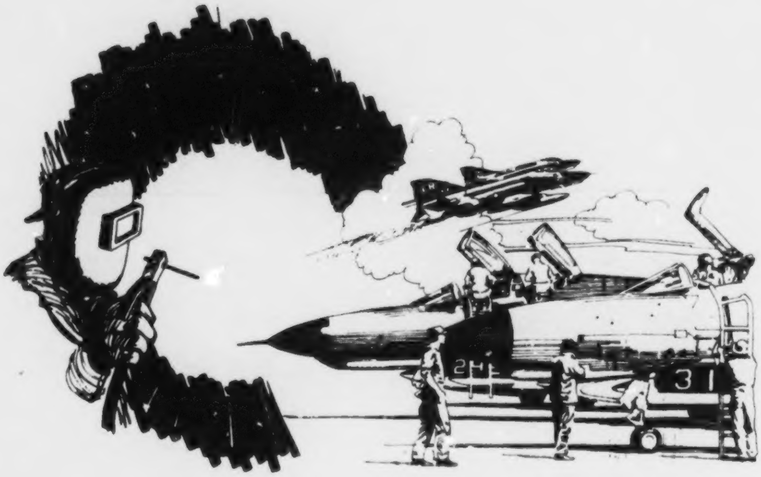
- American Institute of Architects
  1735 New York Avenue, NW
  Washington, DC 20006

- Society of American Registered Architects
  320 North Michigan Avenue
  Chicago, IL 60601

- Association of Collegiate Schools of Architecture
  1735 New York Avenue, NW
  Washington, DC 20006

- The National Council of Architectural Registration Boards
  1735 New York Avenue, NW
  Suite 700
  Washington, DC 20006

GROUP 3: TECHNICIANS



ENGINEERING TECHNICIAN

Nature of the Occupation

Engineering technicians apply the principles and theories of science, engineering, and mathematics to solve problems in research and development, manufacturing, sales, and customer service. Many engineering technicians assist engineers and scientists, especially in research and development. Some work on their own, servicing equipment at customer's work sites. Others work in production or inspection jobs.

Duties may include but are not limited to the following:
- Build or set up equipment
- Prepare experiments
- Calculate and record results
- Make prototype versions of newly designed equipment
- Assist in routine design work
- Prepare materials specifications
- Devise and run tests to ensure product quality
- Study ways to improve manufacturing efficiency
- Supervise production workers
- Serve as field representatives of manufacturers, retailers, or wholesalers
- Help customers install, operate and maintain complex technical equipment
- Write repair or operating manuals

Occupation Specialties

(Dot codes in parenthesis)

Electrical Technicians (003.161-010) apply electrical theory and related knowledge to test and modify developmental or operational electrical machinery and electrical control equipment and circuitry in industrial or commercial plants and laboratories.

Electronics Technicians (003.161-014) apply electronic theory, principles of electrical circuits, electrical testing procedures, engineering mathematics, physics, and related knowledge to lay out, build, test, troubleshoot, repair, and modify developmental and production electronic equipment, such as computers, missile-control instrumentation, and machine-tool numerical controls.

Mechanical-Engineering Technicians (077.161-026) develop and test machinery and equipment, applying knowledge of mechanical engineering technology, under direction of engineering and scientific staff.

Industrial Engineering Technicians (012.267-010) study and record time, motion, methods, and speed of maintenance, production, clerical and other work operations to establish standard production rates and improve efficiency.

Working Conditions

Most engineering technicians work regular hours in laboratories, offices, electronics shops, or industrial plants. Service representatives usually spend much of their time working in customers' establishments. Some may be exposed to electrical shock hazards from equipment.

Tools, Equipment and Materials used may include:
- Measuring and Diagnostic Devices
- Sketches, Diagrams, Layouts, and Drawings
- Computer Terminals
- Calculators
- Graphs
- Machine Tools
- Engineering Specifications
- Stop Watches
- Motion Picture Cameras
- Electrical Recorders

Worker Requirements

You should like:
- Activities involving things and objects
- Tasks of a scientific and technical nature
- Activities involving processes, methods and machines

You should be able to:
- Perform duties that change frequently
- Plan and direct an entire activity
- Make decisions using personal judgment
- Make decisions using standards that van be checked or measured
- Work within precise limits or standards of accuracy

Physically you must:
- Handle, reach, finger, and feel objects
- See well, naturally or with correction

Special Requirements:

Most employees prefer applicants with technical training or college courses in science, engineering and mathematics. Some positions may require additional specialized training and experience.

Opportunities for Experience:

Experience may be obtained through apprenticeship programs or through Armed Forces training and experience programs.

OCCUPATION SPECIALTIES

DOT CODE:

003.161-010	Electrical Technician
003.161-014	Electronics Technician
077.161-026	Mechanical Engineering Technician
012.267-010	Agricultural Engineering Technician

OKLAHOMA
CAREER
SEARCH

ENGINEERING TECHNICIAN

Methods of Entry:

Methods of entering this occupation include direct application to employers and promotion from entry-level jobs. Assistance locating a job may be obtained by consulting newspaper want ads.

Earnings and Advancement

Earnings depend on the education and experience of the employee and whether the employer is with the private sector or the Federal Government. Engineering technicians advance by successful on-the-job experience and by obtaining necessary special training. They may move from routine work to more difficult assignments and some may even become supervisors or engineers.

Earnings:

Median annual earnings of full-time engineering technicians were about $24,400 in 1987. The middle 50 percent earned between $18,000 and $30,400; 10 percent earned less than $14,000 and 10 percent earned over $36,000.

In the Federal Government, engineering technicians could start at $11,802, $13,248 or $14,822, depending on their education and experience.

Fringe Benefits:

Depending on the employer, engineering technicians may receive health and life insurance, paid holidays and vacations, and sick leave.

Career Ladder for this Occupation may look like this:
- Engineer
- Supervisor
- Experienced Engineering Technician
- Entry Level Engineering Technician

Employment and Outlook

In 1987, engineering technicians held about 686,000 jobs. Over two-fifths worked in the manufacturing of electrical and electronic machinery and equipment, transportation equipment and heavy machinery doing engineering work for government, manufacturing or other industries. In 1987, the Federal Government employed about 64,000 engineering technicians.

Employment of engineering technicians is expected to increase much faster than the average for all occupations through the year 2000 due to anticipated increases in research and development expenditures and expected continued rapid growth in the output of technical products.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- High school diploma with vocational education
- Technical junior or community college

Level(s) of education and training also available for this occupation:
- High school diploma with vocational education
- Technical junior or community college

School subjects helpful in preparing for this occupation include:
- Algebra
- Geometry
- Chemistry
- General Science
- Physics
- General Math
- Biology
- Earth Science
- Physical Science

More Sources of Information

- The National Engineering
  Council for Guidance
  1420 King Street
  Suite 405
  Alexandria, VA 22314

- Elect. Tech. Assoc.
  International
  604 North Jackson Street
  Greencastle, Indiana 46135

- International Society of
  Technicians
  2708 West Berry
  Suite 3
  Fort Worth, TX 76109

AIRCRAFT MECHANIC

Nature of the Occupation

Aircraft mechanics, also known as airframe and power plant mechanics, inspect, repair and service all types of aircraft engines and mechanical or hydraulic systems and components of airplanes.

Duties may include but are not limited to the following:
- Repairing, replacing and assembling aircraft parts and frames
- Taking apart and inspecting parts for wear, warping or defects
- Maintaining or replacing hydraulic units, oxygen systems, fuel and oil systems, fire extinguisher systems, and electric systems
- Maintaining and replacing aircraft engines, propeller pumps, and fuel, oil, and water injection systems
- Operating and testing engines and other completed work
- Certifying aircraft is ready for operation

Occupation Specialties

(Dot codes in parenthesis)

Aircraft Accessories Mechanics (621.381-014) repair, test and install aircraft accessories such as power brakes and auxiliary electric motors.

Instrument Repairers (621.281-014) test, repair and replace instruments such as gyroscopic turn-indicators, compasses, pressure valves, tachometers and transducers.

Working Conditions

Aircraft mechanics may work alone or with others under the direction of a supervisor. They may work indoors in clean, well-lighted, well-ventilated and well-equipped hangars or outdoors in all kinds of weather.

Aircraft mechanics usually work 40 hours a week which may include rotating shifts, evening and weekend work. Overtime may be required to complete a project or meet deadlines. Mechanics often work under the pressure of time to maintain flight schedules.

Aircraft mechanics often stand, lie, or kneel in awkward positions and occasionally must work in precarious positions on scaffolds or ladders. Noise and vibration are common when testing engines. Frequently, mechanics must lift or pull as much as 50 pounds.

Aircraft mechanics are generally expected to furnish their own basic hand tools which may cost $600 for an initial set or more than $1,500 for a complete set.

Aircraft mechanics may join a union such as the International Association of Machinists and Aerospace Workers of the Air Transport Division of the Transport Workers Union of America. Members usually pay dues.

Tools, Equipment and Materials used may include:
- Hydraulic Test Equipment
- Propeller Test Bench
- Magna Flux Test
- Sheet Metal Breakers
- Heat-Treat Equipment
- Air or Electric Drills
- Carburetor Flow Tester
- Blueprints, Specifications & Repair Manuals
- Micrometers
- Voltmeters
- Pressure Gauges
- Power Shears
- Arbor Presses
- Drill Presses
- Rivet Guns
- Rules, Tapes
- Center Punches

Worker Requirements

You should like:
- Working with objects and machines
- Activities producing tangible results

You should be able to:
- Work within precise limits or standards of accuracy
- Perform a variety of jobs that often change

OCCUPATION SPECIALTIES

DOT CODE:

621.281-014 Airframe-and-Power-Plant Mechanic
621.381-014 Mechanic, Aircraft Accessories
621.281-014 Instrument Repairer

SOC CODE: 6116

OKLAHOMA
CAREER
SEARCH

AIRCRAFT MECHANIC

- Understand and apply principles of electricity and electronics
- Visualize drawings or pictures as solid objects
- Recognize slight differences in shapes or shadings of objects

Physically you must:
- See and hear well, either naturally or with correction
- Climb onto aircrafts, ladders and scaffolds and maintain balance
- Stoop, bend, kneel, crouch and crawl
- Use your hands easily and skillfully to reach, handle and position parts, and use tools

Special Requirements:

Mechanics who work on civilian aircrafts must be licensed by the Federal Aviation Administration (FAA).

Opportunities for Experience:

Summer employment at small airports under the direction of a licensed mechanic or FAA-approved college or vocational school course work in aircraft mechanics may provide opportunities. The military service also offers opportunities for experience in this area.

Methods of Entry:

Attending an approved school or getting into an apprenticeship program are the best means of learning aircraft mechanics to obtain a license. A list of approved schools or training facilities may be obtained from the Federal Aviation Administration. Methods of entering this occupation include direct application to employers, unions and formal apprenticeship programs. Positions may also be located by consulting vocational schools, college placement offices, or your state employment office.

Earnings and Advancement

Earnings depend upon the employer, geographic location, union affiliation and mechanic's training, experience, seniority, and responsibilities.

Earnings:

In 1987, the median annual salary of aircraft mechanics was $26,000. Mechanics who work on jets generally earn more than those working on other aircraft. The top ten percent of all aircraft mechanics earned over $35,000 a year.

Aircraft mechanics employed by the Federal Government earned an average yearly salary of $25,000 in 1987. Apprentice mechanics usually start at 50 percent of the journeymen wages and work up to full scale pay after three years.

Fringe Benefits:

Depending on the employer, aircraft mechanics may receive paid vacations and holidays; sick leave; life, health, disability, hospitalization and dental insurance; and retirement plans. These benefits are usually paid for, at least in part, by the employer. Aircraft mechanics may also receive free or reduced rates on flights and uniform cleaning allowances.

Career Ladder for this Occupation may look like this:
- Inspector
- Crew Chief
- Licensed Aircraft Mechanic
- Apprentice

Aircraft mechanics may advance through further training and experience.

Employment and Outlook

There were approximately 107,000 aircraft mechanics employed nationally in 1987. Employment is excellent since job openings are expected to exceed the supply of qualified applicants.

Job opportunities will be best in general aviation; keen competition is expected for airline jobs. Opportunities in the Federal Government depend upon defense spending.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- Technical junior or community college
- Apprenticeship

Level(s) of education and training also available for this occupation:
- On-the-job training
- High school diploma or G.E.D.
- High school diploma with vocational education

School subjects helpful in preparing for this occupation include:
- Algebra
- Chemistry
- Electricity & Electronics
- Trigonometry
- Blueprint Reading
- Machine Shop

More Sources of Information

- Professional Aviation
  Maintenance Association
  P. O. Box 248
  500 Northwest Plaza
  Suite 912
  Saint Ann, MO 63074

- Aircraft Mechanics
  Fraternal Association
  Davis Bldg., Suite B
  4150 Cypres Road
  Saint Ann, MO 63074

- Aviation Maintenance
  Foundation, Inc.
  P. O. Box 2826
  Redmond, WA 98073

WELDER

Nature of the Occupation

Welders join metal parts using heat and/or pressure to form a permanent bond. Parts are welded to manufacture products, build structures, or to repair broken or cracked parts.

Duties may include but are not limited to the following:

- Selecting proper welding equipment and accessories
- Adjusting equipment to properly weld materials
- Applying proper heat and/or pressure to bond the materials
- Setting machine guides and work-holding devices
- Aligning and feeding the work piece and removing it after the weld is completed

Occupation Specialties

(Dot codes in parenthesis)

Arc Welders (810.384-014) join metal parts using electric welding equipment.

Gas Welders (811.684-014) use an intense gas flame to join metal parts.

Combination Welders (819.384-010) use arc, gas, or resistance welding equipment on the same project depending on the materials and type of welding needed.

Production Line Welders (819.684-010) join metal parts on a production line using previously set up gas or arc welding equipment.

Working Conditions

Welders may work alone or as part of a team of welders in a plant, building a bridge, or performing work on other large projects.

Welders should be able to withstand heat, work in plants which generally are not air-conditioned, and at times work in the presence of toxic fumes and gases. To prevent injuries caused by extreme heat, welders usually wear protective clothing, goggles, and helmets which may or may not be provided by the employer.

Welders in construction firms normally work outside and may be required to work on scaffolds or platforms.

Welders usually work a 40-hour week on any one of three shifts. Overtime may be required.

Welders may join a union. Members usually pay dues.

Tools, Equipment and Materials used may include:

- Cast Iron
- Aluminum
- Nickel
- Bronze
- Arc & Gas Welding Torches
- Gas Shielded Arc Equipment
- Submerged Arc Welding Equipment

Worker Requirements

You should like:

- Working with machines and tools
- Activities of a routine, organized nature

You should be able to:

- Work well with others
- Make decisions based on measurable data
- Work accurately and precisely from blueprints or written or oral instructions

Physically you must:

- Stoop, kneel, and crouch
- Possess manual dexterity
- See well, either naturally or with correction
- Lift, carry, and transport objects weighing up to 100 pounds

OCCUPATION SPECIALTIES

DOT CODE:

810.384-014	Welder, Arc
811.684-014	Welder, Gas
819.384-010	Welder, Combination
819.684-010	Welder, Production Line

SOC CODE: 7714

OKLAHOMA CAREER SEARCH

WELDER

Special Requirements:
Generally employers prefer applicants who have had high school or vocational school training in welding.

Opportunities for Experience:
Co-op programs may be available through vocational centers, high schools, or community colleges. Formal apprenticeship programs and all branches of the military service also offer opportunities for experience.

Methods of Entry:
Methods of entering this occupation include direct application to employers or local welders' unions. Positions may also be located through an apprenticeship program or by consulting newspaper want ads, school placement offices, or state employment offices.

Earnings and Advancement

Earnings depend upon the size and type of employer, extent of unionization, geographic location, and experience and skill of employee.

Earnings:
Nationally, in 1987, experienced welders earned an average weekly salary of $480. Hourly wages ranged from $10 to $14. Experienced welders in the construction industry earned between $12 and $16 an hour, depending on geographic location.

Apprentice welders earned a starting wage of 50 percent of the experienced welder's wage.

Fringe Benefits:
Depending on the employer, welders may receive paid vacations and holidays; sick leave; health, accident, and life insurance; and retirement. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:

- Supervisor
- Weld Inspector
- Welder Fitter
- Welder
- Helper or Apprentice

Other workers may be hired as resistance machine operators and advance with experience.

Employment and Outlook

There were approximately 414,000 welders and cutters employed nationally in 1987. Employment of welders is expected to remain the same for all occupations through the year 2000.

Job opportunities are not expected to be equally favorable for all kinds of welders. The robot welding systems that are being introduced on manufacturing lines are eliminating the jobs of welding machine operators. Highly skilled welders are not expected to be affected by automation for the foreseeable future. Job openings are expected to vary geographically with the best prospects being in the Sunbelt and western states.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- On-the-job training
- Apprenticeship

Level(s) of education and training also available for this occupation:

- Technical junior or community college

School subjects helpful in preparing for this occupation include:

- Blueprint Reading
- Electricity & Electronics
- Machine Shop
- Metal Shop
- Shop Mechanics
- Cooperative Education-Trade & Industrial
- Industrial Arts
- Mechanical Drawing
- Shop Math
- Welding

More Sources of Information

- American Welding Society
  550 NW LeJeune Road
  Miami, FL 33126

- National Association of Trade and Technical Schools
  P.O. Box 10429
  Dept. BL
  Rockville, MD 20850

- U.S. Department of Education's Center for Education Statistics (available at large public libraries)

- State Employment Offices

- Military Service Recruiters

- Postsecondary Schools with Occupational Programs

Metal/Plastic Working Machine Operator

Nature of the Occupation

Metal working machine operators set up and/or operate metal cutting machines such as lathes, shapers, and milling machines.

Duties may include but are not limited to the following:

- Reading blueprints and working orders to determine tooling instructions
- Positioning cutting tools and workpiece for correct operations
- Determining cutting speeds, feed rates, and cutting tools to be used
- Starting machine and controlling its operation
- Removing chips and controlling coolant systems
- Making minor adjustments or tool changes
- Performing routine machine maintenance burring
- Stacking or loading finished items in shipping containers or placing items on a conveyor system

Occupation Specialties

(Dot codes in parenthesis)

Metal working machine operators usually specialize in one type of machine. Depending on the degree of skill,they may operate one of the following:

Production Milling Machine Operators (605.685-030) set up and operate various types of milling machines to mill flat or curved surfaces on metal workpieces, such as machine, tool, or die parts.

Production Lathe Operators (604.685-026) tend one or more previously set-up lathes, (turret lathes, engine lathes, and checking machines) to perform one or a series of repetitive operations such as turning, boring, threading, or facing metal workpieces.

Working Conditions

Skilled metal and plastic working machine operators generally work in the specialized production departments or tool rooms of factories or job shops under the direction of section leaders and/or supervisors. These machine operators generally work in well-lighted areas. Production operators are generally exposed to more noise and dust in production departments than are skilled machine operators. Hazards common to all metal and plastic workers include metal chips, abrasive dust, sharp cutting tools, revolving parts, and skin irritation caused by oil and coolants.

Most metal and plastic working machine operators work a 5-day, 40-hour week. Some workers are employed on afternoon and night shifts. Overtime may be necessary at times to meet production requirements or contract deadlines.

Most metal and plastic machine operators are members of unions including the International Association of Machinists and Aerospace Workers; the International Union, United Automobile, Aerospace, and Agricultural Implement Workers of America; and the United Steelworkers of America. Metal working machine operators who belong to unions are required to pay dues.

Tools, Equipment and Materials used may include:

- Wrenches
- Mallets & Hammers
- Punches & Chisels
- Micrometers
- Dial Indicators
- Templates
- Clamps
- Vises & Scales
- Blueprints
- Squares & Protractors
- Air, Depth & Surface Gages

Worker Requirements

You should like:

- Working with things and objects
- Doing routine, concrete, and organized work
- Activities of a mechanical nature
- Working with your hands

You should be able to:

- Do exacting work according to specifications
- Solve shop math calculations
- Plan and carry out an entire activity

Physically you must:

- Have good vision, either naturally or with correction
- Stand for extended periods of time

OCCUPATION SPECIALTIES

DOT CODE:

605.685-030	Milling-Machine Operator, Production
604.685-026	Lathe Operator, Production

SOC CODE: 751, 752

Metal/Plastic Working Machine Operator

- Have good depth perception
- Coordinate hand and eye movements
- Lift heavy objects weighing up to about 75 pounds

Opportunities for Experience:
There are several ways to explore or gain experience in the field of machine metal working. They include summer or part-time work as a helper or laborer in a machine shop and co-op programs usually available through a high school, vocational center, or community college.

Methods of Entry:
Methods of entering this occupation include direct application to factories or machine shops. High school and State Employment Security Commission placement offices, local unions, and consulting newspaper want ads also provide assistance.

Earnings and Advancement

Earnings of metal and plastic working machine operators vary according to the skill level of the individual, type of machine operated, geographic location, size of employer, and extent of unionization.

Earnings:
In large cities, the wages of union metal and plastic working machine operators ranged between $9.87 and $13.52 per hour in 1987.

Fringe Benefits:
Depending on the employer, most metal and plastic working machine operators receive paid vacations and holidays; life, accident, disability, and hospitalization insurance; retirement plans; and sick pay. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:

- Tool & Die Maker
- Machinist
- Skilled Machine Operator
- Semi-Skilled Machine Operator
- Trainee

Employment and Outlook

Nationally, there were about 1,003,000 metal working and plastic working machine operators employed in 1987. Employment is expected to change little for all occupations through the year 2000.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- On-the-job training
- High school diploma or G.E.D.

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:

- English
- Machine Shop
- Shop Math
- Industrial Arts
- Metal Shop

More Sources of Information

- United Automobile, Aerospace and Agricultural Implement Workers of America (UAW)
  8000 East Jefferson Avenue
  Detroit, MI 48214

- International Association of Machinists and Aerospace Workers
  1300 Connecticut Ave., NW
  Washington, DC 20036

- The Tool and Die Institute
  777 Buse Highway
  Park Ridge, IL 60068

- National Machine Tool Builders Association
  7901 Westpark Drive
  McLean, VA 22102

- United Steelworkers of America
  Five Gateway Center
  Pittsburgh, PA 15222

- The National Tooling and Machining Association
  9300 Livingstone Road
  Ft. Washington, MD 20744

GROUP 4: TECHNICAL COMMUNICATORS

WRITER AND EDITOR

Nature of the Occupation

Writers develop fiction and nonfiction prose for books, magazines, newspapers, radio and television, brochures, and advertisements. Editors supervise writers, choosing, and preparing material for publication or broadcasting.

Duties may include but are not limited to the following:
- Selecting a topic or being assigned one
- Researching the topic through library study, interviews, and observation
- Selecting and organizing information and writing about the topic to achieve the desired effect
- Revising or rewriting for the best organization or the right phrasing

Occupation Specialties

(Dot codes in parenthesis)

Copy Writers (131.067-014) write to advertise goods and services through print or broadcast media.

News Writers (131.267-014) write news for newspapers, magazines, or news broadcasts.

Technical Publications Writers (131.267-026) write about scientific and technical information in clear language.

Publications Editors (132.037-022) plan the contents and budgets of publications and supervise their preparation.

Assignment Editors (132.137-010) work under an executive editor; they assign writers on particular subjects.

Critics (131.067-018) write critical reviews of literary, musical, or artistic works or performances for broadcast or publication.

Fiction and Nonfiction Prose Writers (131.067-046) write original prose material for publication.

Working Conditions

Some writers work in private offices; others work in crowded, noisy rooms filled with writers and typewriters. Some writers travel to various sites while others spend more time in libraries and on the telephone.

Writers usually work 35-40 hours a week, with occasional overtime. Nights and weekends are required of those who write for morning or weekend publications or broadcasts.

Meeting frequent deadlines, writers need to understand complex information. Demands for the right phrasing can produce stress.

Tools, Equipment and Materials used may include:
- Typewriters
- Electronic Calculators
- Computers
- Tape Recorders

Worker Requirements

You should like:
- Working with words
- Working with a variety of people
- Working with information that requires thought and analysis
- Expressing yourself clearly and imaginatively
- Researching new information

You should be able to:
- Work alone
- Analyze material and sort out details
- Communicate well with clients and co-workers
- Use office machines, especially typewriters
- Work efficiently under deadline pressure

Physically you must:
- Sit at a desk for long periods of time
- See well, naturally or with correction

Special Requirements:

A college degree is generally required; communications and journalism majors are preferred, although a liberal arts degree is desired by some employers.

Jobs in technical writing require a degree in or knowledge of such fields as science, engineering, or business.

Acquaintance with word processing, electronic publishing, and video production equipment for writing and editing is very useful.

Practical experience is expected in newspapers, literary magazines, or radio stations.

Opportunities for Experience:

Summer internships may be available for students. Interns may run errands, answer phones, do research and interviews, and write short articles or advertisements.

Methods of Entry:

Applying directly to employers and taking civil service exams are realistic approaches for entry into this occupation. Some positions are also announced in newspaper want ads, school placement offices, and state employment offices.

OCCUPATION SPECIALTIES

DOT CODE:

131.067-014	Copy Writer	131.267-026	Technical Publications Writer
131.067-018	Critic	131.087-018	Screen Writer
131.267-014	News Writer	132.037-022	Publications Editor
131.067-046	Fiction and Nonfiction Prose Writer	132.137-010	Assignment Editor

SOC CODE: 3210, 3313

OKLAHOMA
CAREER
SEARCH

WRITER AND EDITOR

Earnings and Advancement

Advancement for writers and editors can be achieved within an organization or by moving to another firm. Larger firms usually give writing and editing responsibilities only after a period of entry-level research, fact checking, and proofreading. Smaller firms give major duties upon employment, and competence is expected.

Earnings:

Beginning writers and editorial assistants earned between $18,400 and $29,300 in 1987. Experienced writers and researchers earned salaries ranging between $20,500 and $36,500 a year. Technical writers were paid from $19,300 to $37,800. Editors with experience earned from $20,900 to $39,000 a year.

Copy editors on daily papers in small towns averaged $9,700 in 1987; in cities of 500,000 or more they averaged $13,000. Writers and editors working for the Federal Government earned an average of $28,000 a year. Senior editors on major publications were paid over $60,000 in 1987.

Career Ladder for this Occupation may look like this:

NEWS MEDIA
- Partner/Owner
- Executive Editor
- Associate Editor
- Assistant Editor
- News Writer
- Editorial Assistant

ADVERTISING
- Partner/Owner
- Creative Director
- Copy Supervisor
- Senior Copy Writer
- Copy Writer
- Production Assistant

Employment and Outlook

Writers and editors held about 214,000 jobs in 1987. Their employment may rise faster than the average through the year 2000. Publishers of books, magazines, and newspapers, and nonprofit organizations--including government, business, professional, civic, and religious associations--are expected to increase their staffs. Advertising, public relations, and technical writing are likely to need fresh talent, as are the broadcasting and entertainment industries.

Competition for openings will remain keen, despite high turnover. Business and trade will provide the best opportunities, with small daily and weekly newspapers and small radio and TV stations being other good prospects for beginners. Academic preparation in a field other than writing should help provide both substantial background for a writer and employment, if one cannot get a writing job.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College bachelor's degree

Level(s) of education and training also available for this occupation:
- College bachelor's degree
- College master's degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Business English
- Office Machines
- Typing
- Business Data Processing
- Business Law
- Office Practice

More Sources of Information

- Women in Communications, Inc.
  P.O. Box 9561
  Austin, TX 78766

- American Society of Magazine Editors
  575 Lexington Avenue
  New York, NY 10022

- The Association for Business Communications
  608 S. Wright Street
  100 English Building
  Urbana, IL 61801

- The Dow Jones Newspaper Fund
  P.O. Box 300
  Princeton, NJ 08540

- Society for Technical Communication, Inc.
  815 15th Street, NW
  Suite 516
  Washington, DC 20005

VISUAL ARTIST

Nature of the Occupation

Visual artists create abstract works or realistic images of objects, people, nature, places, and events, with a wide variety of methods and materials, to communicate ideas, thoughts, and feelings. They may use oils, watercolors, acrylics, pastels, chalk, charcoal, pencils, pen and ink, silkscreen, clay, plaster, or other media, including computers, to create works of art.

Duties may include but are not limited to the following:

FINE ARTISTS
- Expressing feelings in art
- Specializing in one or two media
- Selling works to stores, galleries, museums, or collectors

GRAPHIC ARTISTS
- Serving clients' needs with art in advertising, design, packaging, illustration, or cartoons

Occupation Specialties

(Dot codes in parenthesis)

Cartoonists (141.061-010) draw political cartoons, newspaper comics, or comic books.

Fashion Artists (141.061-014) draw stylish illustrations of new clothing fashions.

Illustrators (141.061-022) create pictures for books, magazines, billboards, posters, and record albums.

Medical and Scientific Illustrators (141.061-026) draw precise illustrations of machines, plants, animals, or parts of the human body for business and educational purposes.

Set Illustrators (141.061-030) build and decorate sets for movies, television, and theatrical productions.

Motion Picture Cartoonists (141.081-010) draw series of pictures for animated films shown on TV and in movies.

Working Conditions

Graphic and fine artists generally work in art studios, at home, or in offices. Graphic artists work 40-hour weeks but often work overtime to meet frequent deadlines. Many graphic artists also freelance for occasional clients. Independent visual artists also spend considerable time and effort recruiting potential clients. Some fine artists spend time out of doors in search of subjects.

Tools, Equipment and Materials used may include:
- Airbrushes
- Acid
- Oil Paints
- Watercolors
- Acrylics
- Clay
- Plaster
- Brushes & Matte Knives
- Canvas & Gesso
- Pen & Ink
- Wood
- Stone
- Plastic
- Sponges & Rags
- Models & Still-Life Arrangements
- Power & Hand Chisels
- Computers
- Knives
- Chalk
- Charcoal
- Pastels
- Varnish
- Turpentine & Paint Thinner
- Pencils
- Paper, Cardboard & Board
- Armatures
- Concrete
- Metal
- Wire

Worker Requirements

You should like:
- Expressing emotions
- Working alone and with others
- Translating ideas into visual form
- Satisfying others' expectations

You should be able to:
- Analyze and visualize an artistic task into details
- Communicate well with clients and co-workers
- Use various media
- Work until a project is perfect
- Work against deadlines

Physically you must:
- See well, naturally or with correction
- Have the stamina and health to work late

Special Requirements:

Good preparation for a visual arts career is usually a four-year post-secondary art school program. This training is absolutely essential for scientific and medical illustrators. To demonstrate and exhibit the skills gained, the art works produced in art schools should be collected in a portfolio, including samples of the artist's best work. Before a candidate gains entry into the graphic art field or other art employment, the portfolio will be carefully examined by prospective employers.

Opportunities for Experience:

Many visual artists freelance part-time while in art school, so that they gain both experience

OCCUPATION SPECIALTIES

DOT CODE:

141.061-010	Cartoonist
141.061-014	Fashion Artist
141.061-022	Illustrator
141.061-026	Illustrator, Medical & Scientific
141.061-030	Illustrator, Set
141.081-010	Cartoonist, Motion Picture

SOC CODE: 3250

OKLAHOMA CAREER SEARCH

VISUAL ARTIST

and a professional portfolio. Entry level jobs in advertising and publishing require routine mechanical or paste-up work, but gradually artists are given more responsibility if they show promise.

Methods of Entry:

Visual artists apply directly to employers such as retailers, advertising and graphic design agencies, book publishers, newspapers, governments, manufacturers, and the motion picture industry. Positions may also be found through newspaper ads, school placement offices, and state employment offices.

Earnings:

Salaried visual artists, about 37 percent of artists in 1987, earned an average of $20,000 a year. The middle 50 percent were paid between $15,200 and $26,000 in 1987.

Self-employed visual artists range from part-timers employed in other work to well established graphic, freelance, and fine artists. The former must often accept low fees, the latter can demand high ones.

Fringe Benefits:

Depending on the employer, visual artists on salary can receive paid vacations and holidays, life, accident, and hospitalization insurance; retirement plans, and sick pay. These benefits are paid for, at least in part, by the employer. Self-employed artists, of course, must arrange for their own ways of meeting these costs.

Career Ladder for this Occupation may look like this:
- Partner/Own Business
- Partner
- Creative Director
- Art Director
- Assistant Art Director
- Mechanical Artists
- Freelancer

Self-employed artists may advance as their work circulates and their reputation spreads. Some freelancers remain freelancers, free to choose the type of work they do. Publishers choose these freelancers for specific kinds of illustrations.

Employment and Outlook

Visual artists held about 176,000 jobs in 1987. The 63 percent who were self-employed were either freelancers or fine artists. The main employers for all visual artists are advertising and commercial art firms, publishers, manufacturers, department stores, the motion picture industry, and government. By far, the most visual artists are concentrated in New York City, followed by Boston, Chicago, Los Angeles, and San Francisco.

Visual art work is expected to grow faster than the average through the year 2000. Emphasis is increasing on visual appeal in packaging, marketing, and other communication. Fine artists may find more demand from corporations as well as affluent individuals. Competition will continue to be keen, but fresh talent is usually rewarded.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- High school diploma or G.E.D.
- Technical junior or community college

Level(s) of education and training also available for this occupation:
- High school diploma or G.E.D.
- Technical junior or community college

More Sources of Information

- Graphic Artists Guild
  11 West 20th Street
  New York, NY 10011

- Society of Illustrators
  128 East 63rd Street
  New York, NY 10021

EDUCATIONAL ADMINISTRATOR

Nature of the Occupation

Educational administrators manage school systems to promote satisfactory business and instructional operations for staff members and students. They must plan budgets and courses and hire teachers.

Duties may include but are not limited to the following:

- Formulate and evaluate educational programs and policies
- Direct the preparation and presentation of school budgets
- Determine bond requirements
- Interpret school programs and policies
- Supervise the examination, appointment, training, and promotion of administrative and teaching personnel
- Address community and civic groups to inform and enlist support
- Assist in the selection of school sites, construction of buildings, and provision of equipment and supplies

Occupation Specialties

(Dot codes in parenthesis)

School Superintendents (099.117-022) direct and coordinate activities concerned with the administration of city, county, or other school systems in accordance with board of education policies.

Principals (099.117-018) direct and coordinate the educational, administrative, and counseling activities of elementary, junior high, or high schools.

Vocational Training Directors (097.167-010) supervise and coordinate vocational training programs.

Special Education Directors (094.117-014) formulate programs and policies that relate to the education and training of mentally and physically handicapped children.

Education Supervisors (099.117-026) develop program curriculum, evaluate teaching techniques, and supervise and assist in the hiring and in-service training of teachers.

Working Conditions

Educational administrators supervise other administrative staff members, teachers, or school personnel. They generally work in well-lighted and comfortably heated or air-conditioned offices.

Educational administrators usually work 12 months a year and may work more than 40 hours a week. Special school events, community meetings, and conferences often require evening attendance and travel.

Educational administrators may join professional associations directly related to their level of administration such as the National Association of Elementary School Principals or the National Association of Secondary School Principals. Members pay periodic dues.

Worker Requirements

You should like:

- Activities concerned with the communication of data
- Activities involving business contact with people

You should be able to:

- Reason clearly and logically
- Make decisions using personal judgment
- Direct and plan an entire activity or the activities of others

OCCUPATION SPECIALTIES
DOT CODE:

099.117-018	Principal
099.117-026	Supervisor, Education
097.167-010	Director, Vocational Training
094.117-014	Director, Special Education
099.117-022	Superintendent, Schools

OKLAHOMA
CAREER
SEARCH

EDUCATIONAL ADMINISTRATOR

- Relate well to people as well as gain their support
- Understand the meanings and relationships of words and use them effectively
- Perform mathematical operations quickly and accurately

Physically you must:
- Talk and Hear

Special Requirements:
Most educational administrators have had experience as a certified classroom teacher and have advanced through further education. A master's degree or Ph.D. may be a requirement in some school districts.

Opportunities for Experience:
An appointment as an acting or assistant administrator or an administrative internship may be available.

Methods of Entry:
Methods of entering this occupation include direct application to school districts. Positions may also be located by consulting professional journals, newspaper want-ads, college placement offices, and the state employment office.

Earnings and Advancement

Earnings depend upon the employer, geographic location, and employee's training, experience, and level of supervision.

Earnings:
Principals of elementary schools earned an average yearly salary of $41,536 in 1987. Junior high and middle school principals earned an average salary of 44,861. Principals of senior high schools earned an average yearly salary of $47,896 in 1987. Assistant principals earned the following salaries in 1987: senior high school--$39,758; junior high school--$37,958; and elementary school--$34,347. School superintendents earned an average yearly salary of $64,700 in 1987.

Fringe Benefits:
Educational administrators may receive paid vacations and holidays, hospitalization and health insurance, retirement programs, and sabbatical leaves.

Career Ladder for this Occupation may look like this:
- Superintendent
- Principal
- Assistant Principal
- Education Supervisor
- Teacher

Educational administrators may advance through experience and increased responsibility and administrative duties.

Employment and Outlook

There were approximately 288,000 educational administrators employed nationally in 1987. Employment of educational administrators is expected to grow more slowly than the average through the year 2000.

Although openings for principals are expected to increase, competition for school administrative positions will continue.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- College master's degree
- College Ph.D. or professional degree

Level(s) of education and training also available for this occupation:
- College bachelor's degree

School subjects helpful in preparing for this occupation include:
- College Preparatory
- Speech
- Accounting
- Economics
- Political Science
- Sociology
- English
- Child Growth & Development
- Bookkeeping
- Government
- Psychology

More Sources of Information

- American Association of School Administrators
  1801 North Moore Street
  Arlington, VA 22209

- National Association of Secondary School Principals
  1904 Association Drive
  Reston, VA 22091

- National Association of Elementary School Principals
  1615 Duke Street
  Alexandria, VA 22314-3406

- Public and Private Higher Education Institutions

PUBLIC RELATIONS SPECIALIST

Nature of the Occupation

Public relation specialists plan and conduct public relations programs to promote products, ideas, companies, or people. They influence opinions through promotional techniques and two-way communications.

Duties may include but are not limited to the following:

- Determining the needs of the company or individual
- Preparing and distributing fact sheets, photographs, articles, news releases, and/or promotional booklets
- Making speeches, conducting research
- Directing advertising campaigns in all types of media
- Coordinating special exhibits, contests, or luncheons into the total public relations plan

Occupation Specialties

(Dot codes in parenthesis)

Sales-Service Promoters (165.167-010) generate sales and create good will for a firm's products by preparing displays and touring the country. They call on merchants to advise them of ways to increase sales and demonstrate products.

Working Conditions

Public relations specialists may work alone or with a team on a particular project. The work is often done in comfortable, well-lighted, and ventilated offices. Public relations specialists usually work 35 to 40 hours a week, 5 days a week. A public relations specialist's routine consists of preparing and delivering speeches, attending meetings and community activities, and out-of-town travel. Many times overtime is required and sometimes specialists are on call around the clock.

Public relations specialists may belong to the Public Relations Society of America. Members pay periodic dues.

Tools, Equipment and Materials used may include:

- Typewriters
- Cameras
- Telephones
- Audio-Visual Equipment
- Surveys & Reports
- Showcases
- Charts
- Interview Forms
- Account Records

Worker Requirements

You should like:

- Communicating with people
- Abstract and creative work

You should be able to:

- Influence and react to people's ideas and attitudes
- Project self-confidence, speak clearly
- Communicate ideas and information verbally and in writing
- Evaluate information and make quick judgments and decisions
- Plan, control, and complete projects from start to finish
- Deal with people in all situations

Physically you must:

- Lift and carry light materials
- See and hear well, either naturally or with correction

Opportunities for Experience:

Summer work at radio and television stations, at newspaper offices, and volunteer work with charitable and community organizations can provide experience in this field.

Methods of Entry:

One method is to apply directly to civil service offices, advertising agencies, newspapers, radio and television stations, businesses, or industries. Assistance may also be obtained from college placement offices and newspaper want ads.

OCCUPATION SPECIALTIES

DOT CODE:

165.067-010	Public Relations Representative
165.167-010	Sales-Service Promoter

SOC CODE: 332

OKLAHOMA
CAREER
SEARCH

PUBLIC RELATIONS SPECIALIST

Earnings and Advancement

Earnings vary by the type of business, location, and size of employer. Private consulting firms generally pay more than companies that have their own public relations departments. Those who work in public relations firms often receive substantial salary increases based on successful performance.

Earnings:

Nationally, in 1987, median annual earnings for public relations specialists were $26,900, with a range between $14,230 and $51,500. The middle 50 percent earned between $19,700 and $41,200 a year. Top-level public relations practitioners in all organizations earned an average salary of $42,200.

Public relations executives employed by large companies could earn more than $51,000 annually. Public relations specialists graduating with a bachelor's degree and employed by the Federal Government earned a starting salary of $18,400 in 1987.

Those graduating with a master's degree earned a starting salary of $22,500. Public relations specialists employed by the Federal Government earned an average salary of $32,600 in 1987.

Fringe Benefits:

Public relations specialists may receive an expense account; hospital and life insurance; sick leave; paid vacations and holidays; and retirement plans. These benefits are usually paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:

- Own Business
- Supervisor
- Public Relations Specialist
- Public Relations Trainee

A successful career depends on individual ability, initiative, self-confidence, desire, capacity for hard work, and experience.

Employment and Outlook

Nationally, in 1987, there were approximately 95,000 public relations specialists employed. Employment is expected to grow much faster than the average for all occupations as corporations, associations, medical centers, and other large organizations expand their public relations efforts. There will be keen competition for beginning jobs since the diversified nature of the occupation attracts many applicants. Prospects for a career in public relations are best for highly-qualified applicants--talented people with sound academic preparation and some media experience.

Related Education and Training

Level(s) of education and training usually needed for this occupation:

- Technical junior or community college
- College bachelor's degree

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:

- College Preparatory
- English
- Speech
- Humanities
- Sociology
- Composition
- Journalism
- Typing
- Psychology

More Sources of Information

- Public Relations Society of America
  845 Third Avenue
  New York, NY 10022

- Women Executives in Public Relations
  P. O. Box 781
  Murray Hill Station
  New York, NY 10156

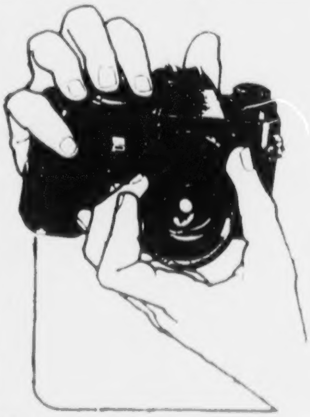
- American Association of Advertising Agencies
  666 Third Avenue
  13th Floor
  New York, NY 10017

- International Public Relations Association, U.S. Section
  250 W. Floresta Way
  Menlo Park, CA 94025

- College Placement Offices

- Local, State, and Federal Civil Service Offices

PHOTOGRAPHER & CAMERA OPERATOR



Nature of the Occupation

Photographers and camera operators use cameras and film to photograph or film people, places, and events. In order to visually record ideas and events they need a thorough understanding of camera operation, lighting, composition, darkroom procedures, and the special characteristics of film and papers. Photographers may specialize in portraits, advertising, or other distinct photography. Camera operators film news events, television shows, movies, commercials, and cartoons.

Duties may include but are not limited to the following:

- Carefully arranging lighting and composition of the picture
- Using makeup, lights, reflectors, screens, and props
- Mixing and developing chemicals
- Developing and printing film
- Enlarging, reducing, and retouching prints

Occupation Specialties

(Dot codes in parenthesis)

Still Photographers (143.062-030) photograph subjects using still cameras, color or black and white film and a variety of photographic accessories. They may specialize in a particular type of photography such as illustrative, portrait, fashion, commercial, or architectural and be designated accordingly.

Photojournalists (143.062-034) photograph newsworthy events, locations, people, or other materials for use in publications or telecasts. They usually specialize in one phase of photography such as news, sports, or special features.

Motion Picture Photographers (143.062-022) use their knowledge of motion picture techniques to photograph various subjects and subject matter for use in television productions, movies, promotional and training films, or scientific and medical films.

Aerial Photographers (143.062-014) photograph segments of earth from aircraft to produce pictures used in surveying, mapping, archaeology, volumetric surveying, recording the effects of pollution or natural disasters, determining the condition of crops or timberland, and planning cities and other large-scale projects.

Scientific Photographers (143.062-026) photograph a variety of subject matter to illustrate or record scientific phenomena or data.

Animation Camera Operators (143.382-010) operate special cameras to make animated cartoon motion picture films.

Working Conditions

Photographers may work alone or with an assistant. Most work inside under pleasant conditions, while others work outside and are required to handle heavy and bulky equipment. Sometimes their work can be physically demanding.

Salaried photographers generally work a standard 5-day, 40-hour week and receive time and a half for overtime. Freelance photographers usually work longer hours, including evenings and weekends. Photojournalists may be called to cover an event whenever it occurs. Freelance, news, and commercial photographers travel frequently and may work in uncomfortable surroundings. Sometimes the work can be dangerous, especially for photojournalists assigned to cover stories on natural disasters and armed conflicts.

Many photographers work under pressure. Deadlines and demanding customers must be satisfied.

Photographers usually own several cameras and lenses. Some develop and print their own photographs, others send their work to photographic laboratories for printing.

Photojournalists are usually members of The Newspaper Guild. Members usually pay dues.

OCCUPATION SPECIALTIES

DOT CODE:

143.382-010	Camera Operator, Animation	143.062-030	Photographer, Still
143.062-014	Photographer, Aerial	143.062-022	Photographer, Motion Picture
143.062-026	Photographer, Scientific	143.062-034	Photojournalist

SOC CODE: 326

OKLAHOMA
CAREER
SEARCH

PHOTOGRAPHER & CAMERA OPERATOR

Tools, Equipment and Materials used may include:
- Cameras
- Film
- Enlargers & Automated Printers
- Lenses & Colored Filters
- Electronic Flash Units, Floodlights, Reflectors & Tripods

Worker Requirements

You should like:
- Communicating information to others

You should be able to:
- See detail and differences in shapes and shadings
- Work within precise limits or standards of accuracy
- Have a feeling for form and symmetry
- Use your imagination and be original in your thinking

Physically you must:
- Talk, hear and see well, either naturally or with correction, including color vision
- Have good manual dexterity and hand-eye coordination
- Reach for, handle, and feel things

Opportunities for Experience:

Photography as a hobby, work on the school yearbook, and the military services offer opportunities for experience in this field. Experience is also available through participation in a formal apprenticeship program.

Methods of Entry:

Methods of entering this occupation include applying directly to employers and photographic supply houses and completing an apprenticeship program. Positions may be located by consulting professional associations and unions, school and college placement offices, newspaper want ads and state employment offices.

Earnings and Advancement

Earnings are determined by assignments and locations of work. Although freelance and self-employed photographers may earn more than salaried workers, their earnings are greatly affected by business conditions and their community.

Earnings:

Nationally, in 1987, photographers and camera operators employed in private industry earned salaries ranging from $16,600 to $35,100, depending upon the difficulty of work performed.

Photographers working for daily newspapers under contracts negotiated with The Newspaper Guild after two years of work earned from $300 to $500 a week in 1987, with the majority earning from $316 to $432. Fully experienced photographers earned from $400 to $750 a week after six years, depending on the size and location of the publication.

Photographers employed by the Federal Government earned an average yearly salary of $23,900 in 1987. Some freelance and self-employed photographers earn more than salaried workers; many do not. Their earnings are, in effect, determined by the hours they work, the quality of their product, their marketing ability, business climate, location, and clientele.

Career Ladder for this Occupation may look like this:
- Own Business
- Photographer
- Trainee/Apprenticeship

Most employers strongly prefer hiring individuals with two or more years of college training and courses in photography.

Employment and Outlook

There were approximately 109,000 photographers and camera operators employed nationally in 1987. Employment is expected to grow at a faster than average rate through the year 2000. Employment of portrait and commercial photographers is also expected to grow rapidly with scientific and medical research photography offering the best opportunities. Photojournalism jobs may grow slowly. As the entertainment industry expands, jobs for movie and video camera operators should also grow, but competition will remain intense for such jobs.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- On-the-job training
- Technical junior or community college
- Apprenticeship

Level(s) of education and training also available for this occupation:
- Less than a high school diploma
- College bachelor's degree

School subjects helpful in preparing for this occupation include:
- Art
- General Math
- Photography
- Chemistry

More Sources of Information

- Professional Photographers of America
  1090 Executive Way
  Des Plaines, IL 60018

- American Society of Photographers
  Box 52900
  Tulsa, OK 74152

RADIO OPERATOR

Nature of the Occupation

Radio operators send and receive messages following procedures prescribed by federal regulations.

Duties may include but are not limited to the following:
- Turning on power control switches for transmitting and receiving equipment
- Turning dials to set frequency and other controls
- Monitoring the control panel to make sure that components are working correctly
- Maintaining communication systems by making routine tests
- Keeping logs of transmissions and records of testing results

Occupation Specialties

(Dot codes in parenthesis)

There are several areas of specialization within this occupation.

Transmitter Operators (193.262-038) test, monitor, control, and repair radio transmitters to broadcast radio and television programs.

Radiotelegraph Operators (192.262-030) control and maintain equipment used in radiotelegraph communications, relaying messages to the addressees by telephone or teletype. They also call ships or stations by code and monitor emergency distress calls.

Radiotelephone Operators (192.262-034) control and repair radiotelephone transmitting and receiving equipment used for commercial communications.

Photoradio Operators (193.362-010) send and receive radio photographs. They develop negatives, print photographs, and repair equipment as needed.

Working Conditions

Radio operators may work alone or in teams with other operators, communications technicians, engineers, ships' captains, pilots, navigators, or police and emergency personnel.

Most radio operators work in comfortable, though confined, work areas which are usually clean and well-lighted. A few operators work outdoors, sometimes under adverse weather conditions.

Radio operators may be subject to constant noise from radio communications or from the conversations of other personnel. Maintenance equipment occasionally exposes radio operators to high voltage electrical circuits.

Generally, radio operators work a 40-hour week. In order to meet deadlines or during emergencies, they may be required to work overtime. In many establishments, 24-hour radio operation is required. Consequently, radio operators may work assigned hours on day, afternoon, midnight, or swing shifts, and may sometimes be on call at all hours. Shift assignments may include weekends and holiday work. Operators employed in the transportation field may travel considerably.

Radio operators may join one or more professional associations or unions such as the National Association of Broadcasters. Members pay periodic dues.

Tools, Equipment and Materials used may include:
- Hand Tools
- Transformers & Batteries
- Radio Transmitters & Receivers
- Radar & Other Navigational Equipment
- Recording & TV Equipment
- Communications Equipment
- Electronic Testing & Monitoring Systems
- Schedules & Log Books
- Diagrams & Charts
- Reference & Instructional Manuals

Worker Requirements

You should like:
- Doing scientific and technical work
- Working with equipment and machinery

You should be able to:
- Interpret instructions that are written and spoken
- Follow exact standards and regulations
- Perform a variety of duties
- Stay alert for long periods of time
- Work well under pressure
- Learn codes, symbols, and technical language

Physically you must:
- See and hear, either naturally or with correction
- Speak rapidly, clearly, and distinctly
- Use your hands skillfully

Special Requirements:

Most radio operators must be licensed by the Federal Communications Commission (FCC). To obtain a license, an

OCCUPATION SPECIALTIES

DOT CODE:

193.262-038	Transmitter Operator
193.262-030	Radiotelegraph Operator
193.262-034	Radiotelephone Operator
193.362-010	Photoradio Operator

SOC CODE: 393

OKLAHOMA CAREER SEARCH

RADIO OPERATOR

applicant must pass a series of examinations given by the FCC. Licensing requirements are usually governed by the type of transmission involved and whether an operator's duties include making adjustments to transmitters. To obtain a first-class radiotelegraph operator's permit, you must be 21 and have at least one year of experience. Radio officers who work on ships must be licensed by both the FCC and the U.S. Coast Guard. Military installations require security clearance for radio operators.

Opportunities for Experience:
Learning Morse code, participating in radio hobby groups, and building and operating an amateur radio station provide experience. Part-time or summer work in communications or electronics may be helpful. All branches of the military services offer experience.

Methods of Entry:
The most common method of entry is through direct application to employers. Schools, professional associations, and unions may provide information on job opportunities.

Earnings and Advancement

Earnings of radio operators vary according to the individual's education and experience, employer, geographic location, and job specialty. The type of FCC license held will also affect earnings.

Earnings:
In 1987, broadcast operators earned an average yearly salary of $21,698. In 1987, federal government radio operators with at least a third-class license earned annual starting salaries of $14,390 or $17,824. Supervisors earned from $16,788 to $29,190 per year.

Fringe Benefits:
Fringe benefits may include health, life, and disability insurance; paid vacations and holidays; sick leave; and retirement plans. These benefits may be paid for, at least in part, by the employer.

Career Ladder for this Occupation may look like this:
- Supervisor Radio Operator
- Radio Operator

Another Career Ladder may look like this:
- Radio Chief
- Chief Airline-Radio Operator
- Airline-Radio Operator

Advancement of radio operators may be determined by experience, the FCC license held, job performance, and education.

Employment and Outlook

There were approximately 12,000 radio operators employed nationally in 1987. Employment of radio operators is expected to grow as fast as the average for all occupations through 1990.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- On-the-job training
- Technical junior or community college

Level(s) of education and training also available for this occupation.

School subjects helpful in preparing for this occupation include:
- Speech
- Electricity & Electronics
- Typing

More Sources of Information

- National Association of Broadcasters
  1771 N Street, NW
  Washington, DC 20036

- National Association of Broadcast Employees and Technicians
  7101 Wisconsin Avenue
  Suite 800
  Bethesda, MD 20814

- National Radio Broadcasters Association
  2033 M Street, NW
  Washington, DC 20036

WORD PROCESSOR

Nature of the Occupation

Word processors or word processing machine operators use the automated or electric keyboards or consoles of word processors to record, edit, store, and revise correspondence, reports, statistical tables, forms, and other materials. Word processors consist of a keyboard, a video display terminal, and a printer, and may have such "add-on" capacities as optical character recognition readers. Material may be stored on floppy disks, hard disks, magnetic tape, or magnetic cards.

Duties may include but are not limited to the following:

- Positioning and loading the console with blank tapes, cards, or disks
- Inserting paper into the typewriter carriage
- Setting controls for margins, spacing, and tabulation
- Typing from the typed or handwritten draft or from machine dictation
- Reading copy for errors
- Searching for a specific set of stored, typed characters in order to make changes
- Retyping and adding or deleting letters, words, or lines to correct errors
- Moving paragraphs and/or columns and reformatting the document, as necessary
- Removing the copy and recording from the machine
- Keeping a log of reference numbers and data recorded on each tape, card, or disk
- Filing tapes, cards, disks, correspondence, and reports

Occupation Specialties

(Dot codes in parenthesis)

Magnetic Tape Typewriter Operators (203.582-034) operate magnetic tape typewriters and tape consoles to type positive proof copy and simultaneously produce master tape for automatic reproduction of such finished texts as letters, reports, and other data from manuscripts or pretaped material.

Photocomposition-Keyboard Operators (203.582-046) operate keyboards of computer terminals equipped with video display screen to record data from manuscript for storage and retrieval into and from computer system for subsequent reproduction as printed matter.

Terminal Operators (203.582-054) operate on-line computer terminals to transmit data to or to receive data from computers at remote locations.

Transcribing-Machine Operators (203.582-058) operate typewriters to transcribe letters, reports, or other recorded data through earphones of transcribing (voice-reproducing) machines.

Working Conditions

Beginning word processors generally work under the supervision of a more experienced worker or a clerical supervisor. Some may work under the direction of the office supervisor.

Word processors usually work in clean, well-lighted, and ventilated offices. Large offices may be noisy from office machines or people talking. Although the work is seldom hazardous, the possibility of eyestrain exists because of the need to pay close attention to detail and/or monitor a CRT for long periods of time. They must be able to sit for long periods of time.

Most word processors work a 5-day, 35 to 40-hour week.

Tools, Equipment and Materials used may include:

- Word Processing Machines
- Files & Paper
- Forms
- Ribbon Cartridges
- Machine Dictation/Transcription Units
- Magnetic Tapes, Cards, or Floppy or Hard Disks
- Print Wheels or Typing Elements
- Tape Erasers
- Teleprocessing Terminals

Worker Requirements

You should like:

- Activities of a routine, definite, and organized nature
- Activities involving machines, processes, or methods
- Activities concerned with the communication of information

You should be able to:

- See detail in objects or drawings and recognize slight differences in shapes or shadings
- See details and recognize errors in numbers, spelling, and punctuation in written materials, charts, or tables, and punctuation in written materials, charts, or tables
- Determine correct grammar, punctuation,and spelling for information received orally

OCCUPATION SPECIALTIES

DOT CODE:

203.362-022	Word-Processing Machine Operator
203.582-034	Magnetic Tape Typewriter Operator
203.582-046	Photocomposition Keyboard Operator
203.582-054	Terminal Operator

SOC CODE: 4793

OKLAHOMA
CAREER
SEARCH

WORD PROCESSOR

- Repeat tasks of short duration according to a set procedure
- Work within precise standards of accuracy
- Make decisions based on verifiable data, using standards that can be checked or measured

Physically you must:
- Sit for long periods
- Reach for, handle, finger, and feel objects
- Coordinate the movement of eyes and hands or fingers
- See well, either naturally or with correction

Special Requirements:

Employers generally prefer to hire high school graduates who can meet their requirements for typing speed and accuracy. Applicants are expected to have previous word processing training or experience. Good spelling, punctuation, and grammar skills are essential, and familiarity with a variety of office equipment and procedures is helpful to a word processor seeking employment. Applicants for government jobs must pass civil service examinations.

Opportunities for Experience:

Training in word processing and summer or part-time clerical jobs may offer a chance to sharpen skills and observe the duties of a word processor first hand. Secondary vocational education programs in business and office cluster and postsecondary education programs in word processing also may offer practical experience through a co-op portion.

Methods of Entry:

High school and business school placement services help interested persons find employment in this occupation. Applicants should apply at business personnel offices and look at classified ads in newspapers. Assistance in locating jobs may also be obtained from local offices of state employment offices. Persons interested in obtaining employment with government agencies should apply at federal, state, or local civil service offices.

Earnings and Advancement

Earnings of word processors vary according to their experience, level of responsibility, employer, and geographic location.

Earnings:

Earnings were generally highest for those working in the New York area and on the west coast, and in the machinery and aerospace industries. Word processors employed in the private sector earned average annual salaries ranging from $14,000 to $18,100, depending on the complexity of the work and the level of responsibility. Depending on the city where employed, word processing trainees earned average weekly salaries ranging from $236 to $298; operators averaged from $274 to $364; level I specialists averaged from $320 to $416; and level II specialists ranged from $351 to $442 on a weekly average in 1987. Supervisors averaged from $403 to $522 a week in 1987.

Career Ladder for this Occupation may look like this:
- Word Processing Supervisor
- Word Processor
- Trainee

Employment and Outlook

In 1987, there were 1,002,000 typists, including word processors, employed in all sectors of the economy. About one-third worked for business firms; another one-third worked for educational institutions, hospitals, law offices, and business service firms; and about one-fourth worked for federal, state, and local governments.

Employment of word processors is expected to decline through the year 2000, due to the greatly increased productivity of office workers that has resulted from the widespread use of automated office equipment. There will continue to be substantial openings because of the many word processors who retire or transfer to other occupations.

Related Education and Training

Level(s) of education and training usually needed for this occupation:
- High school diploma or G.E.D.

Level(s) of education and training also available for this occupation:
- High school diploma or G.E.D.

School subjects helpful in preparing for this occupation include:
- Blueprint Reading
- Shop Math
- Building Trades & Carpentry
- Wood Shop

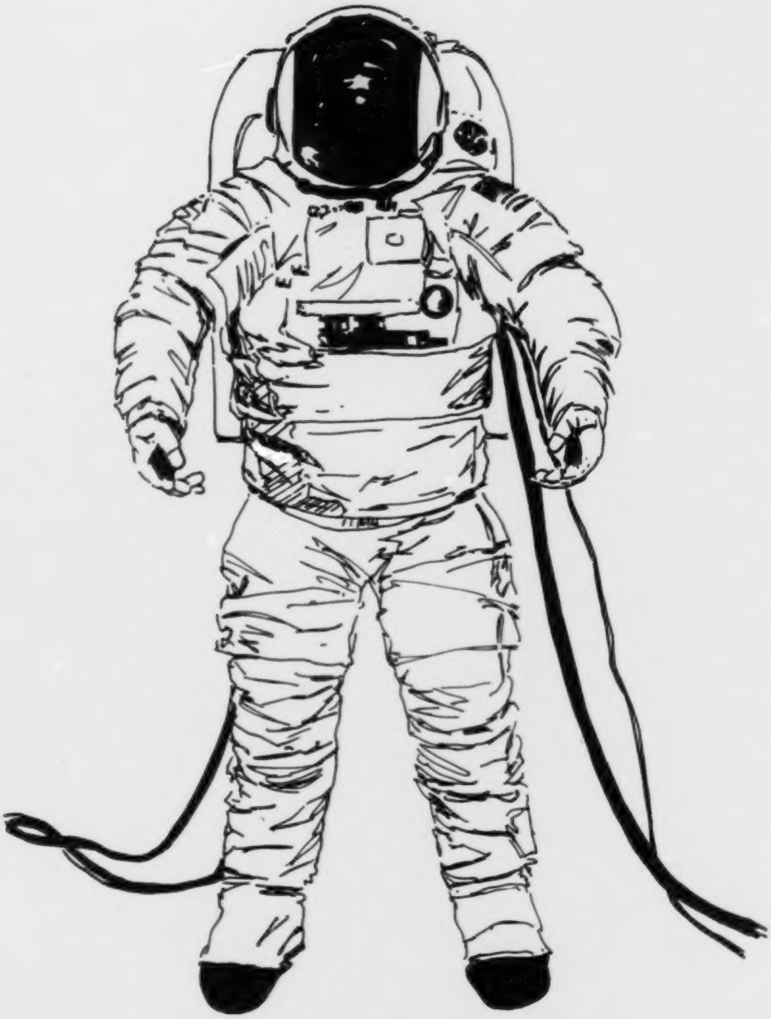
More Sources of Information

- Association of Information Systems Professionals
  1015 N. York Road
  Willow Grove, PA 19090

- National Association of Professional Word Processing Technicians
  110 W. Byberry Road
  Philadelphia, PA 19116

- Professional Secretaries International
  301 E. Armour Boulevard
  Kansas City, MO 64111

GROUP 5: CREW MEMBERS



ASTRONAUT

Nature of the Occupation

Astronauts are also known as commanders, pilots, mission specialists, and payload specialists. These individuals are responsible for flying/landing the space shuttle or conducting experiments while in orbit.

Duties may include but are not limited to the following:
- Deploying and/or retrieving satellites
- Maintaining onboard equipment and satellites
- Conducting scientific research
- Interpreting research data
- Performing basic crew operations (ex. changing air filters)

Occupation Specialties

Commander/Pilot—Fly space or aircraft.

Mission Specialists—Conduct the experiments during flight; are skilled in payload operations.

Payload Specialists—Perform scientific or technical investigations; are selected by the company or agency whose payload is being flown on that particular mission.

Working Conditions

Astronauts, mission specialists, and payload specialists work in very clean and comfortable environments. They usually work on teams and most of their time (90-95%) is devoted to the preparation of one specific mission.

They usually work 40 hours a week, although overtime maybe necessary to simulate actual in-flight operations.

Worker Requirements

You should like:
- Working as part of a team
- Flying
- Working with your hands
- Activities of a scientific and technical nature

You should be able to:
- Think creatively
- Understand and use scientific theories
- Perform a variety of duties
- Work in confined areas
- Work under pressure
- Make quick, logical decisions
- Communicate well, both orally and written

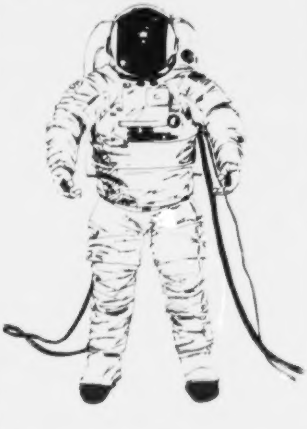
Physically you must:
- Possess excellent eye, hand, and finger coordination
- See well, either naturally or with correction
  Pilots—Distance visual acuity: 20/50 or better uncorrected; correctable to 20/20 each eye
  Mission Specialist—Distance visual acuity: 20/100 or better uncorrected; correctable to 20/20 each eye
- Be in excellent condition

Special Requirements:

Pilots—Pilot candidates are required to have a bachelor's degree from an accredited institution in engineering, biological science, physical science, or mathematics. An advanced degree or equivalent experience is desirable. To meet the minimum qualifications, the applicant must have at least 1,000 hours pilot-in-command time in high-performance jet aircraft. The pilot applicant must be able to pass a NASA Class 1 space-flight physical.

Mission Specialists—Mission specialists are required to hold a bachelor's degree from an accredited institution in engineering, biological or physical science, or mathematics. Although NASA only requires a bachelor's degree, it is unlikely that an individual will be selected as a candidate with only a B.S. A majority of the mission specialists hold several advanced degrees in several different disciplines (2-3 Master's degrees and 2-4 Ph.D's).

Payload Specialists—The position for payload specialist is selected by the company or agency whose payload is to be flown on that particular mission. These individuals usually have been involved with the development of the payload equipment and have trained on the equipment for several years. NASA retains the final selection authority for payload specialists, to ensure those chosen are fully qualified and can function as part of the flight crew.



ASTRONAUT

Earnings and Advancement

Military: Crew members on active duty and on loan from the military to NASA receive the normal compensation for the military rank that they have attained for their particular service branch.

Civilians: Mission specialists earned an average salary of $40,000 in 1988. Payload-specialists salaries are determined by the company that they are employed with.

Related Education and Training

Level(s) of education and training usually needed for these occupations:

- Several advanced degrees in engineering, physical or biological science, or mathematics
- Greater than 1,000 hours in pilot-in-command training in high-performance jet aircraft (pilot/commander)

School subjects helpful in preparing for this occupation:

- Technology Education
- Algebra
- Chemistry
- Physics
- Biology
- Calculus
- Trigonometry
- Geometry
- Physiology
- English
- Statistics
- Engineering (any related field)

More Sources of Information

- National Aeronautics and Space Administration Regional Center Education Offices

- NASA John C. Stennis Space Center
  Bay St. Louis, MS 39529

To request NASA educational services, please contact the Education Officer at the NASA Center that serves your state or territory.

If you live in	Write
Alaska, Arizona, California, Hawaii, Idaho, Montana, Nevada, Oregon, Utah, Washington, Wyoming	NASA Ames Research Center Moffett Field, CA 94035
Connecticut, Delaware, District of Columbia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont	NASA Goddard Space Flight Center Greenbelt, MD 20771
Colorado, Kansas, Nebraska, New Mexico, North Dakota, Oklahoma, South Dakota, Texas	NASA Lyndon B. Johnson Space Center Houston, TX 77058
Florida, Georgia, Puerto Rico, Virgin Islands	NASA John F. Kennedy Space Center Kennedy Space Ctr., FL 32899
Kentucky, North Carolina, South Carolina, Virginia, West Virginia	NASA Langley Research Center Langley Station Hampton, VA 23665-5225
Illinois, Indiana, Michigan, Minnesota, Ohio, Wisconsin	NASA Lewis Research Center 21000 Brookpark Road Cleveland, OH 44135
Alabama, Arkansas, Iowa, Louisiana, Missouri, Tennessee	NASA George C. Marshall Space Flight Center Marshall Space Flight Center, AL 35812
Mississippi	NASA National Space Technology Laboratories Building 1200 NSTL, MS 39529

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY

UNIT I

STUDENT SUPPLEMENT 2—JOB-INFORMATION REPORT FORM

Directions

Use the following form for gathering and comparing information about the specific jobs you wish to explore in Assignment Sheet 3.

Nature of the occupation ______________________________

Working conditions ______________________________

STUDENT SUPPLEMENT 2

Worker requirements ______________________________

____

____

____

____

____

____

____

____

____

____

____

____

Earnings and opportunities ________________________

____

____

____

____

____

____

____

____

____

____

____

____

STUDENT SUPPLEMENT 2

Employment outlook ______________________________

Education/training required ______________________________

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 3—JOB-COMPARISON WORKSHEET

Directions In the boxes under the column heading "Job Choices," list the five jobs you reported on in Assignment Sheet 3. In the boxes under the column heading "Advantages," list beside each job choice the advantages you imagine each job would have. In the boxes under the heading "Disadvantages," list beside each job choice the disadvantages you imagine each job would have.

Job choice	Advantages	Disadvantages
1.		
2.		

STUDENT SUPPLEMENT 3

Job choice	Advantages	Disadvantages
3.		
4.		
5.		

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 4—CAREER OBJECTIVES

Directions In the blank provided at the top of this form, write your career goal. Then, using the job information you have gathered, list under the proper heading the education and training you will need, the equipment you will need, and jobs you think you will need to obtain in order to reach your career goal. These lists will become your career objectives.

Career goal ______________________________

Education and training required to meet your career goal

STUDENT SUPPLEMENT 4

Equipment needed to meet your career goal

STUDENT SUPPLEMENT 4

Jobs required to meet your career goal

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 5—WHAT YOU CAN DO THIS YEAR

Directions Review the three lists you made in Student Supplement 4 and then select short-term objectives from those lists. Write these short-term objectives under the proper heading on this form.

Short-term objectives for education and training needed to meet your career goal

Short-term objectives for equipment needed to meet your career goal

STUDENT SUPPLEMENT 5

Short-term objectives for jobs required to meet your career goal

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 6—WHAT YOU CAN DO IN HIGH SCHOOL

Directions Review the three lists you made in Student Supplement 4 and then select from those lists long-term objectives you can meet while you are in high school. Write these long-term objectives under the proper heading on this form.

Long-term educational and training objectives you can meet while you are in high school

Long-term equipment-need objectives you can meet while you are in high school

STUDENT SUPPLEMENT 6

Long-term job objectives you can meet while you are in high school

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 7—WHAT YOU CAN DO AFTER HIGH SCHOOL

Directions Review the three lists you made in Student Supplement 4 and then select from those lists long-term objectives you can meet after you graduate from high school. Write these long-term objectives under the proper heading on this form.

Long-term educational and training objectives you can meet after you graduate from high school

Long-term equipment-need objectives you can meet after you graduate from high school

STUDENT SUPPLEMENT 7

Long-term job objectives you can meet after you graduate from high school

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 8—CAREER PLAN OF ACTION

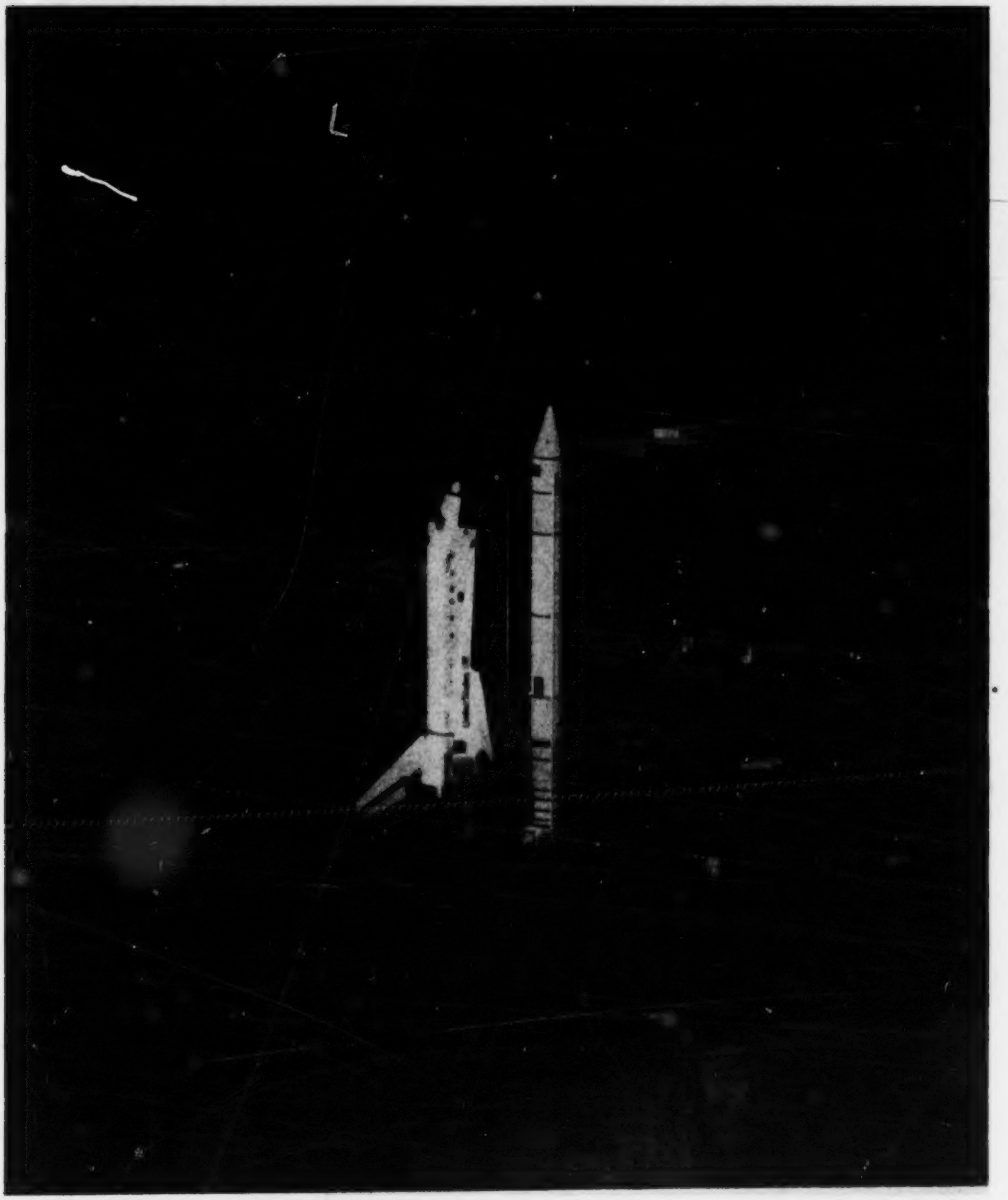
Directions Review the lists you have made in Student Supplements 5, 6, and 7 and assign dates to each objective. Using these lists and dates, complete this form by listing all your objectives according to the dates you have assigned.

Career goal ______________________________

Year	Objective

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

STUDENT SUPPLEMENT 9—LIFE ABOARD THE SPACE SHUTTLE



Courtesy of NASA, Lyndon B. Johnson Space Center.

People can live and work in space

The idea that ordinary people would someday live and work in space has fascinated serious scientists and engineers as well as science fiction fans. NASA's Space Shuttle is the first step in turning this dream into reality.

The Space Shuttle is a reusable aerospace vehicle that takes off like a rocket, maneuvers in orbit like a spacecraft, and lands like an airplane.

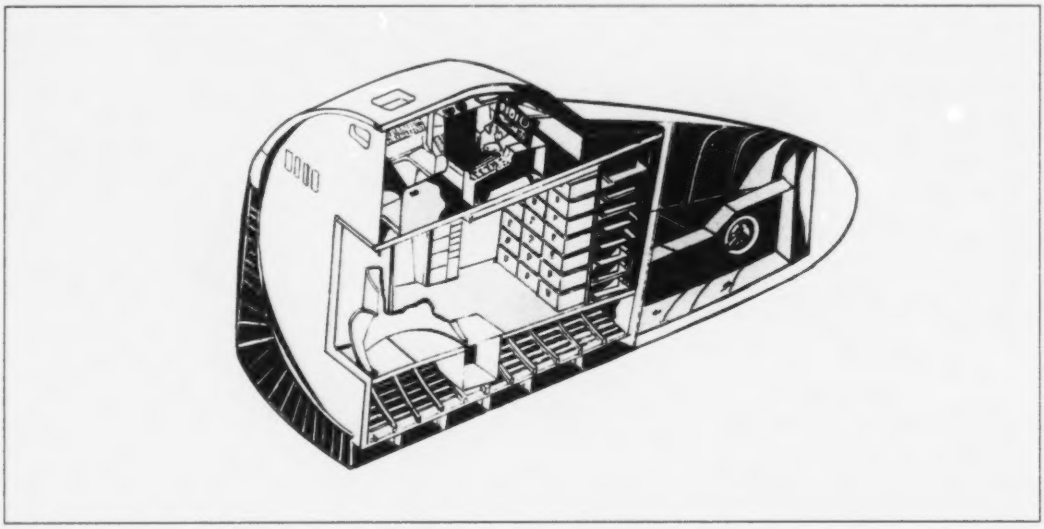
The Shuttle orbiter, a delta-winged spaceplane about the size of a DC-9 commercial jetliner, carries people and cargo between the ground and Earth orbit. It can also be used as an observation post in space, and as a space platform for a fully equipped laboratory for medical, scientific, engineering, and industrial experiments.

One of the key attributes of the Space Shuttle is the relatively low gravity forces exerted on crew and passengers during launch and reentry. Launch and reentry forces are about 3 g's (three times normal gravity)—well within the limits that can be tolerated by healthy persons. Thus, people of average health—not necessarily in perfect physical condition—can travel in space.

Living accommodations

Orbiter living accommodations are relatively comfortable, because they incorporate advances made through nearly two decades of experimental manned space missions and extensive ground studies. The crew cabin is roomy for a spaceship, with 71.5 cubic meters (2,525 cubic feet) of space.

There are two floors inside the pressurized cabin, or "nose" section, of the orbiter. On the top level, or *flight deck*, the commander and pilot monitor and control a sophisticated array of equipment that puts the cockpit of a giant jetliner to shame. Behind their seats is a work area where Shuttle crew members operate experiments and check out spacecraft that are carried inside the orbiter's cavernous cargo bay.



The orbiter's two-story crew cabin contains a flight deck on the top level and living quarters underneath. This cutaway view shows the left side of both stories. Redrawn with permission of NASA, John F. Kennedy Space Center.

The bottom level, called the *mid deck*, is the living area of the orbiter, although experiments may also be carried on here if required. The mid deck contains lockers for stowing crew equipment, and facilities for sleeping, eating, and waste disposal.

Air

Living in the orbiter's pressurized atmosphere requires only ordinary clothing. People can move about, work, and relax unencumbered by bulky space suits.

Air pressure inside the orbiter is the same as Earth's at sea level: 1,033 grams per square centimeter (14.7 pounds per square inch). This air is made up of 80 percent nitrogen and 20 percent oxygen. Earth's atmosphere is 78 percent nitrogen, 21 percent oxygen, and 1 percent other gases such as argon and neon.

The orbiter's cabin fans circulate its air through cleansing filters. The filters, changed on a regular basis, contain activated charcoal to remove odor from the air, and lithium hydroxide to remove carbon dioxide. Excess moisture is also removed, keeping humidity at comfortable levels. Temperature in the orbiter can be regulated between 16 and 32 degrees Celsius (61 and 90 degrees Fahrenheit).

Menu

For crews of at least six people or a space flight of more than seven days, a galley "mission kit" can be loaded in the orbiter mid deck. The galley includes special serving trays that separate the different food containers and keep them from lifting off and soaring around in the weightless cabin. It also has a convection-type oven where packages of food are warmed before going into the tray. A small dining area consisting of a table and several foot loops is also optional. The foot loops are floor restraints that help the astronauts steady themselves in the zero-gravity environment. Earth-bound chefs might envy meal preparation on the orbiter—one crew member can ready meals for four people in about five minutes (excluding heating time).

About half of the Shuttle foods and beverages are preserved by dehydration, which saves weight and storage space. There is ample water for rehydration, since it is a by-product of the fuel cells which generate electricity. (Both hot and cold water are available.) Some foods are thermo-stabilized, that is, they are heat sterilized and then sealed in conventional cans or plastic pouches. A few, such as cookies and nuts, are available in ready-to-eat form.

Courtesy of NASA, Lyndon B. Johnson Space Center.

Shuttle meals are tasty and nutritious. The orbiter menu includes more than 70 food items and 20 beverages. With so many different items, Shuttle travelers can have a varied menu every day for four days.

What are the orbiter meals like? A typical day's menus include orange drink, peaches, scrambled eggs, sausage, cocoa, and a sweet roll for breakfast; cream of mushroom soup, ham and cheese sandwich, stewed tomatoes, banana, and cookies for lunch; and shrimp cocktail, beefsteak, broccoli au gratin, strawberries, pudding, and cocoa for dinner.

Menus provide about 3000 calories daily although crew members are not required to eat everything. Previous space missions demonstrated that astronauts need at least as many calories in space as they do on Earth.

Studies have shown that despite zero gravity, most foods can be eaten with ordinary spoons and forks as long as there are no sudden starts, stops, or spinning. The surface tension and stickiness of the food holds it together and on the utensil. As a result, dining in space is almost like dining on Earth.

Sanitation

Sanitation is more important within the confines of the orbiter than on Earth. Space studies have shown the population of some microbes can increase extraordinarily in a confined weightless area such as a spacecraft cabin. This could potentially spread illness to everyone on board. As a result, not only the eating components but also the dining area, toilet, and sleeping areas are regularly cleaned. Since there are no washing machines in space, trousers (changed weekly), socks, shirts, and underwear (changed every two days) are sealed in airtight plastic bags after being worn. Garbage and trash are also sealed in plastic bags.

Shuttle travelers don't have to do many dishes. Containers are thrown away (stored in the trash bags), and eating utensils and trays are cleaned with wet wipes.

A favorite early question of people interested in space was how the astronauts took care of digestive elimination. The orbiter travelers use a toilet very much the same as one on Earth. Airflow substitutes for gravity, carrying wastes to the bottom of the toilet. The waste goes directly into a container which is open to vacuum when the toilet is not in use.

Some of the waste may be used for post-flight laboratory analyses. In the past, such analyses have told doctors which minerals are lost excessively in space, and have helped to increase their understanding of body functions.

Orbiter travelers have facilities and supplies available for sponge baths while in space. They are able to obtain water from a watergun. Water temperature can be set at any comfortable level from 18 to 35 degrees C (65 to 95 degrees F).

Because of weightlessness, water droplets tend to float about in the cabin. This can be not only a nuisance, but also potentially hazardous to equipment and crew. To prevent this from happening, an airflow system directs waste water into the orbiter's waste-collection system, where the waste water is sealed in plastic watertight bags.

If whiskers cut off in shaving floated about weightlessly in a cabin, they could be a nuisance and even foul up equipment. An astronaut can avoid this problem by using conventional shaving cream and a safety razor, then cleaning off his face with a disposable towel. A windup shaver that works like an electric razor is available as a backup.

Unisex space suits

In the past, space suits were tailor-made for each astronaut, a time-consuming and costly process. Now only the gloves are custom-fitted. The Shuttle space suit is manufactured in small, medium, and large sizes, and can be worn by either men or women. The suit comes with an upper and lower torso equivalent to a shirt and trousers, and the two pieces snap together with seal rings. A life-support system is built into the upper torso. Previous pressure suits had separate life-support systems that had to be connected to the suits.

The Shuttle space suit is lighter, more durable, and easier to move about in than previous space suits.

For the first few Shuttle flights (the orbital flight tests), astronauts wore pressure suits—not spacesuits—like the kind worn by military jet pilots, during launch and atmospheric reentry of the spacecraft. Now that the Shuttle is operational, crew members wear regular clothing at all times, just like the crew and passengers of an airliner.

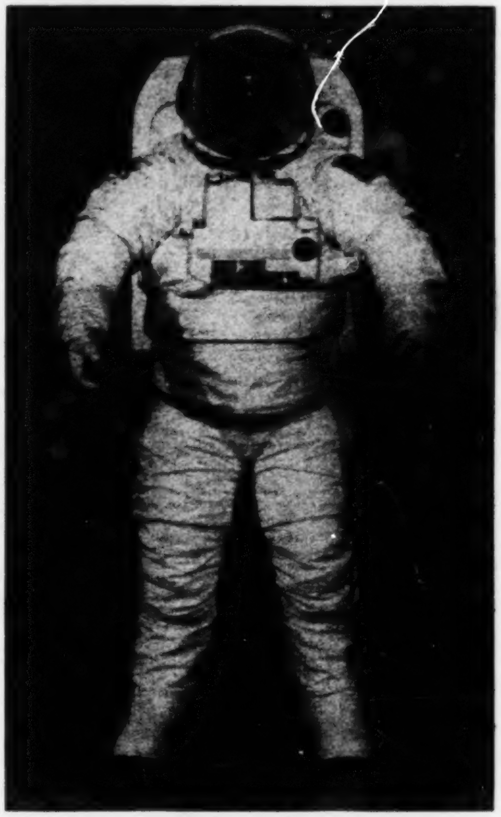
The Shuttle suit will be used for extravehicular activity, such as when an astronaut has to work outside the spacecraft.

The two suits provided on each flight are normally assigned to the commander and the ranking mission specialist (the astronaut responsible for managing orbiter equipment). For emergency use, personal-rescue enclosures are available for the other crew members.

The personal-rescue enclosure is an 83.36-centimeter (34-inch) diameter ball containing life support and communications gear. Each is designed to protect one person.

If an orbiter becomes inoperable in space and cannot return to Earth, the nonsuited crew will enter their personal-rescue enclosures and the pilot and mission specialist will don their space suits. The suited astronauts will transfer their persons in the personal-rescue enclosures from the disabled vehicle to the rescue ship.

They can accomplish the transfer by carrying the enclosures, by attaching them to the remote manipulator arm of the rescue ship (normally used for deploying payloads), or by rigging a pulley and clothesline device between both spacecraft and attaching the enclosures so they can be pulled from one craft to the other.



Courtesy of NASA Headquarters, Washington, D.C.

Recreation and sleep

Just as on Earth, recreation and sleep are important to good health in space. A scientifically planned exercise program is provided, largely as a countermeasure for the atrophy of muscles in a weightless environment. Cards and other games, books, writing material, and tape recorders and tapes, to chronicle personal observations or to listen to music, are also available.

Sleeping accommodations aboard the Shuttle depend upon the requirements of each mission and the preferences of individual crew members.

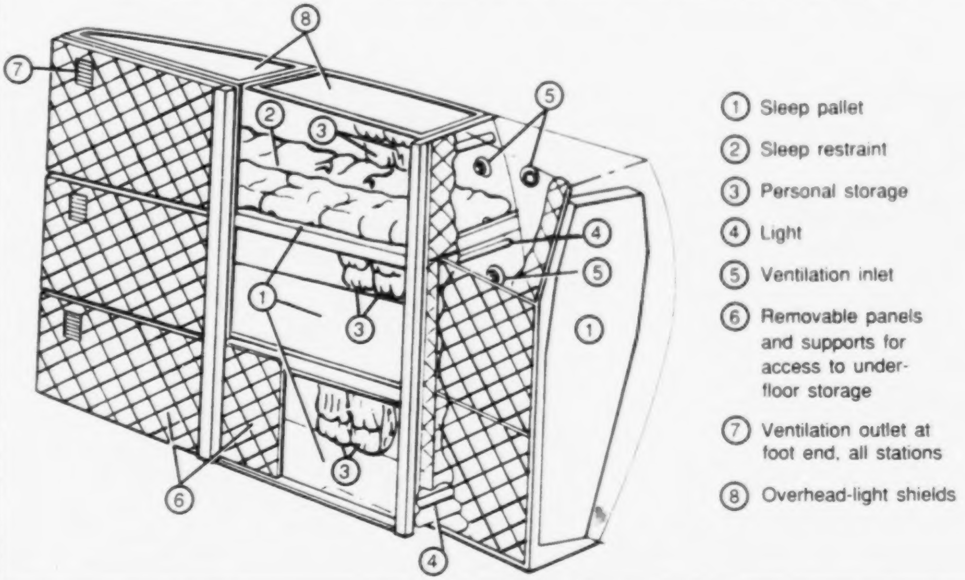
On the Shuttle's first flight, the astronaut crew slept in the commander and pilot's seats in the orbiter cockpit—to keep a better eye on their brand-new spaceship. Later crews either slept in their seats, in sleeping bags, or in detachable bag liners, or simply tethered themselves to the walls of the orbiter.

The sleeping bags are cocoon-like restraints attached to the lockers where crew provisions are stored. In zero-gravity there is no "up" position, and an astronaut is oriented in his/her sleeping bag as if sleeping standing up.

Starting with STS-9, a bunkbed mission kit can be loaded aboard the Shuttle. This will allow the crew members to sleep in three horizontal bunks built into the wall, plus an extra vertical bunk if needed. Each bed comes complete with an individual light, communications station, fan, sound-suppression blanket, and sheets with zero-gravity restraints. The bunks will even have pillows.

On following flights, up to four optional sleeping bags can be used in case the bunks must be removed to allow space for a special experiment.

The Shuttle orbiter can be outfitted with up to four bunks, three horizontal and one vertical.


⑧
⑦
②
③
⑤
④
⑤
①
③
①
③
⑥
④
① Sleep pallet
② Sleep restraint
③ Personal storage
④ Light
⑤ Ventilation inlet
⑥ Removable panels and supports for access to under-floor storage
⑦ Ventilation outlet at foot end, all stations
⑧ Overhead-light shields

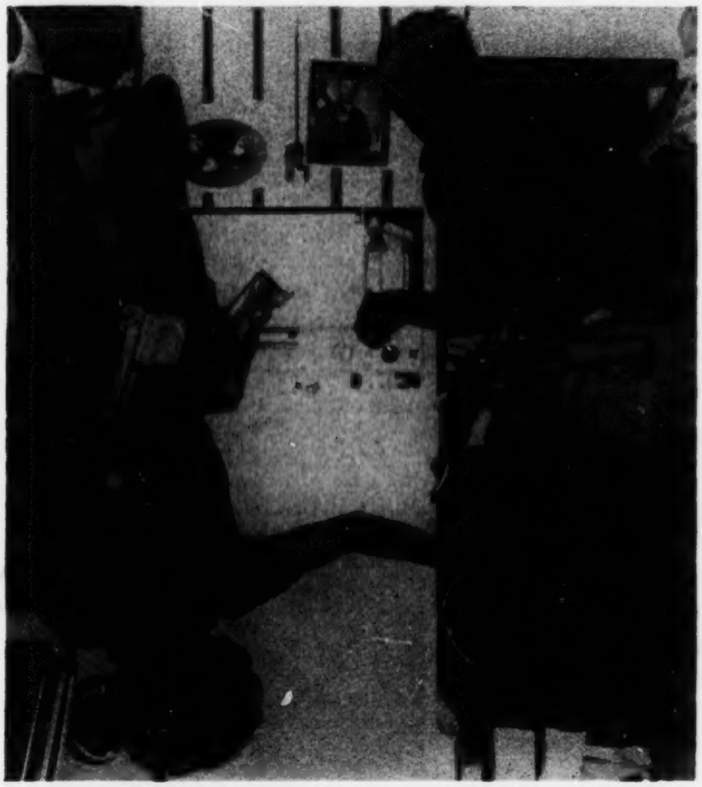
Redrawn with permission of NASA, John F. Kennedy Space Center.

Weightlessness

Many of the problems of going into space have been resolved. However, the physiological effects of weightlessness are still not completely understood. Among them are leaching of minerals from bones, reduction in rate of bone formation, atrophy of muscles when not exercised, and motion sickness.

All the deleterious effects astronauts have experienced from zero gravity have so far reversed after their return to normal gravity on Earth. In addition, some of the effects have been countered while in space by exercise and food supplements.

However, even vigorous exercise in space does not appear to stop bone loss or the decrease in the rate of bone formation. As a result, NASA is engaged in an intense and sustained effort aimed at understanding the cause underlying these changes, and then developing ways to prevent them. The increased information about body functions derived from this effort will pave the way for prolonged missions in space and contribute to our understanding of the physiology of living things on Earth.



Courtesy Lyndon B. Johnson Space Center.

Life Aboard the Space Shuttle adapted from *NASA Facts* with permission of NASA (National Aeronautics and Space Administration), John F. Kennedy Space Center, Florida, 1985.

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

ASSIGNMENT SHEET 1—GATHER PERSONAL INFORMATION

Name ______________________________

Introduction

We all have certain *interests*—things, subjects, or activities in life that we like to do, or things that make us happy. Conversely, we all have certain things, subjects, or activities that we dislike.

We all also have certain *aptitudes*—a talent or potential for being able to do something—and *skills*—activities we know how to perform because we have been trained to do them and have practiced doing them. And, we all hold certain *values*—personal judgments concerning the importance or worth of a thing or quality.

Each occupational area has certain requirements that are necessary in order for a person to be able to perform the jobs within that area successfully.

By figuring out your interests, dislikes, aptitudes, skills, and values and then comparing them to requirements necessary for success in the jobs in various occupational and career-interest areas, you can learn much about possible career options you may choose to investigate.

One method you can use to discover your interests, dislikes, aptitudes, skills, and values is through an informal self-inventory. Self-inventories often consist of open-ended statements or questions that ask you to examine your preferences in specific areas.

For example, to discover and examine your **interests** and **dislikes**, you might be asked questions such as Do you prefer to spend your time with people? Or do you prefer to work on problems—maybe by writing, thinking, daydreaming, or reading? Do you spend most of your time tinkering with machines, doing carpentry, cooking, or working on a car? What activities did you enjoy as a child? What courses do you enjoy? What are your hobbies?

Such questions can give you clues about your career interests. If you answer that you enjoy courses that include lots of discussions, you might like a job working with people. Or if you answer that you like to work alone on projects, you might prefer a career that involves working with data or things.

In examining your **aptitudes**, you may be asked questions over three aptitude areas: school-subject, physical, and mental.

ASSIGNMENT SHEET 1

Questions that can help you identify your aptitudes in school subjects might include Which subjects are most enjoyable for you? In which do you receive the best grades? Which subjects are most difficult for you? In which did you receive the poorest grades? A good analysis of your school subjects will provide you with many clues to your aptitudes.

You should also analyze your physical aptitudes, since these affect the type of job for which you should apply. Questions that help you analyze this aptitude area include Do you have any physical handicaps that prevent you from working in certain occupations? What is your personal energy level? Are you basically healthy? Energetic? Alert? Do you have enough strength to do certain jobs?

A third aptitude area to examine is your mental capabilities. Can you add, subtract, multiply, and divide numbers easily? Can you work with fractions? Can you communicate effectively and easily?

Skills are often thought of as activities that have to do with manual training. Such skills as typing, sewing, carpentry, repairing an engine, and operating a cash register are easy to identify. However, other skills are also important and should be included in your skills analysis. The following questions can be useful in your skills analysis. Have you had any special training or experience in communication, such as public speaking or debate? Have you had special training in music, such as piano or singing lessons? Have you had special training or experience in working with people such as volunteer work for charitable organizations? What special training have you had in foreign languages, technology education/industrial arts, mathematics, home economics, science, fine arts, etc.? These subjects may have provided you with the skills that are needed for various careers.

You do not think about your **values** a lot. They are usually learned from your parents and you live by them automatically. But examining your values is an important aspect of making wise decisions that will help you gain more satisfaction from your future job.

Values are things people believe important or worthwhile. The following are ten things that people value and may also effect their job satisfaction.

- High pay
- Security (not having to worry about losing your job)
- Independence (being able to work alone)
- Routine (having a regular way of doing things)
- Variety (having many different things to do)

ASSIGNMENT SHEET 1

- Authority (having power over others)
- Creativity (being able to use your imagination)
- Respect (feeling important or recognized)
- Contribution to society (being able to change society for the better)

Asking you to rank these ten values has been found to be a good way of helping you examine the work values that are important to you.

Exercise **Self-inventory**

Directions Your goal in this exercise is to get enough information about yourself so that you can define your interests, aptitudes, skills, and values—Step 1 in the career decision-making process. To do so, complete the following five-part self-inventory, then discuss your answers with someone whose opinion you respect.

Section A: Interest inventory

1. Do you like to work with people?

   Yes ______ No ______

2. Do you like to work on mechanical things?

   Yes ______ No ______

3. Do you like to work with facts and figures?

   Yes ______ No ______

4. Do you like to discuss important issues?

   Yes ______ No ______

5. Do you like being outdoors?

   Yes ______ No ______

6. Do you like to read?

   Yes ______ No ______

7. Do you like to write?

   Yes ______ No ______

ASSIGNMENT SHEET 1

8. What three school subjects have you liked best? Why?

Subject a. ______________________________

Reasons for liking subject ______________________________

____

____

Subject b. ______________________________

Reasons for liking subject ______________________________

____

____

Subject c. ______________________________

Reasons for liking subject ______________________________

____

____

9. What three school subjects have you liked least?

Subject a. ______________________________

Reasons for disliking subject ______________________________

____

____

Subject b. ______________________________

Reasons for disliking subject ______________________________

____

____

Subject c. ______________________________

Reasons for disliking subject ______________________________

____

____

ASSIGNMENT SHEET 1

10. If you have participated in any school activities, organizations, or clubs, which two have you liked best and why?

Organization a. ______________________

Reasons for liking organization ______________________

____

____

Organization b. ______________________

Reasons for liking organization ______________________

____

____

11. If you have participated in any school activities, organizations, or clubs, which two have you liked least and why?

Organization a. ______________________

Reasons for disliking organization ______________________

____

____

Organization b. ______________________

Reasons for disliking organization ______________________

____

____

____

12. What two activities do you most like to do in your spare time?

Activity a. ______________________

Activity b. ______________________

ASSIGNMENT SHEET 1

13. What two chores or tasks at home, on the job, or in volunteer work do you really enjoy?

    Chore/task a. ______________________________

    Chore/task b. ______________________________

14. What three things have you liked most about school?

    a. ______________________________

    b. ______________________________

    c. ______________________________

15. What three things have you liked least about school?

    a. ______________________________

    b. ______________________________

    c. ______________________________

Section B: Aptitudes inventory

1. In which three school subjects do you do your best work or receive your best grades?

    Subject a. ______________________________

    Subject b. ______________________________

    Subject c. ______________________________

2. In which three school subjects did you have the most difficulty or receive your poorest grades?

    Subject a. ______________________________

    Subject b. ______________________________

    Subject c. ______________________________

3. Can you write clearly and correctly?

    Yes ______ No ______

4. Can you add, subtract, multiply, and divide?

    Yes ______ No ______

ASSIGNMENT SHEET 1

5. Can you work with fractions and percentages?

   Yes ______ No ______

6. Are you comfortable when talking with adults?

   Yes ______ No ______

7. Are you able to give a speech?

   Yes ______ No ______

8. Do you read well and understand what you've read?

   Yes ______ No ______

9. Do you get along well with people?

   Yes ______ No ______

10. Do you have musical or artistic talent?

    Yes ______ No ______

11. Are you good in athletics?

    Yes ______ No ______

12. Have you been a leader or held a responsible office in any organization?

    Yes ______ No ______

Section C: Skills inventory

1. What business, office, or industrial machines can you operate?

   ____

   ____

   ____

2. What special training in communication, social skills, or the fine arts have you received?

   ____

   ____

   ____

ASSIGNMENT SHEET 1

3. What special training have you received in subjects you have taken in school?

____

____

____

Section D: Values inventory

The following are ten items many people value in their work. On the blanks beside the items, rank from 1 to 10 the things you want most from your work.

______ High pay

______ Security

______ Independence

______ Creativity

______ Routine

______ Variety

______ Authority

______ Creativity

______ Respect

______ Contribution to society

Section E: Evaluation

1. Considering your answers to the interest inventory above, what are your three main interests?

Interest a. ______________________________

Interest b. ______________________________

Interest c. ______________________________

ASSIGNMENT SHEET 1

2. Considering your answers to the aptitude and skills inventories above, what three things do you do well?

   a. ______________________________

   b. ______________________________

   c. ______________________________

3. Reviewing your ranking of the values inventory above, list the three things you value most from work.

   a. ______________________________

   b. ______________________________

   c. ______________________________

4. Share the information you have recorded in this exercise with your guidance counselor, vocational education teacher, parents, or anyone else you trust. On the blanks below, list any aptitudes, interests, skills, or values you discover as a result of this conversation.

   a. ______________________________

   b. ______________________________

   c. ______________________________

Introduction and self-inventory adapted from *Getting the Job* by Richard L. Lynch, Gregg Division, McGraw-Hill Book Company, copyright 1977.

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY

UNIT I

ASSIGNMENT SHEET 2—GATHER GENERAL JOB INFORMATION AND IDENTIFY OCCUPATIONAL AND CAREER-INTEREST AREAS OF CHOICE

Name ____

Introduction

You are enrolled in a course of study that can introduce you to an interesting, rewarding, though often demanding, career field—the aerospace industry. The industry is full of opportunities for qualified people and offers jobs that involve a wide variety of skills and various working conditions.

In this assignment sheet, you will get a sample of the different occupations in the aerospace industry and be given an opportunity to start thinking about the type of work you might want to do within the industry. Then you will be able to start looking for an occupation that matches up with what you learned about your interests, aptitudes, skills, and values in Assignment Sheet 1.

Careers can be classified into two categories: occupational areas and career-interest areas. An *occupational area* is a large group or cluster of jobs similar in the nature of the work being performed. A *career-interest area* is another large grouping of jobs similar in the interests of the people performing them. Career-interest areas represent a kind of work activity that takes place in many different occupational areas.

Read the following sections of this introduction. These sections will give you an overview of the types of activities performed in the occupational and career-interest areas of the aerospace industry. As you read these sections, make notes on the fields of work that seem to match the interests, aptitudes, skills, and values you learned about yourself in Assignment Sheet 1.

Occupational areas in the aerospace industry

The following is a list of the occupational areas in the aerospace industry.

Communication. Jobs in the area of communication are involved with changing information into messages that can be transmitted.

The workers included in this occupational area include people who set up, operate, and maintain electronic equipment used to record and transmit radio and television programs as well as those who maintain and operate electronic transmitting equipment such as telephone, telegraph, and satellite systems, and those who write, edit, store, and revise printed materials such as correspondence, reports, statistical tables, forms, books, and magazine articles.

ASSIGNMENT SHEET 2

Construction. Jobs in the construction area involve using manufactured goods and materials to build structures on site. These structures may be made from wood, metal, masonry, or stone.

Typical occupations in this area include carpenters, electricians, sheet-metal workers, architects, and designers. Typical job duties include using hand and power tools to construct, erect, and repair structures according to specifications; laying out, assembling, installing, maintaining, and testing electrical fixtures, equipment, and wiring used in lighting, power, communications, air conditioning, and electrical systems; and laying out, fabricating, assembling, and installing and maintaining metal products.

Manufacturing. Jobs in this area involve using raw materials and processes to produce products that are used elsewhere.

Workers in the manufacturing area control machinery to create changes or reactions in chemicals during the processing of raw materials into industrial or consumer products; join metal parts using heat and/or pressure to form a permanent bond; weld parts to form manufactured products or to repair broken or cracked parts; and set up, operate, and service the machines and tools used in the manufacturing processes.

Energy, power, and transportation. Jobs in energy, power, and transportation involve converting energy into mechanical, fluid, and electrical power.

Workers in the energy, power, and transportation occupational area direct the operation of transportation services; design, develop, and test aircraft, space vehicles, surface effect vehicles, missiles, and systems for use in the Earth's atmosphere and outer space; and operate, inspect, repair, and service all types of aircraft airframes and engines and mechanical or hydraulic systems and components associated with aircraft.

Career-interest areas in the aerospace industry

Scientists. Scientists are people whose job interests include studying how the universe operates, observing the natural world, creating hypotheses to explain their studies and observations, and then carrying out experiments to validate their hypotheses.

Some scientists do research on living things—some on nonliving things. They all perform experiments under controlled conditions, but some scientists test hypotheses or discover new ways of doing things while others develop useful ways of applying research.

Aerospace scientists study the properties of superalloys used in jet engines; investigate the properties of polymers that may be used in aircraft and spacecraft; investigate the behavior of healthy

ASSIGNMENT SHEET 2

and diseased cells in separation chambers; seek clues to the origin of life in the chemical components of Earth rocks, Moon rocks, and meteorites; and analyze the effect of the solar wind on a comet's plasma tail.

Engineers. Engineers interests must include applying physical and mathematical principles to solve specific real-world problems. Solutions provided by engineers advance the design and construction of jets, computers, satellites, and spacecraft.

Aerospace engineers who work for NASA evaluate new aircraft designs by computer simulation; study the effects of lightning on airborne computer systems; evaluate wind-shear sensors; calculate correct orbits for spacecraft rendezvous; analyze space-shuttle electrical needs, and design computers to monitor experiments.

Technicians. People who become technicians must enjoy building, operating, and maintaining the complex equipment that bring engineers' designs to life.

Aerospace technicians calibrate and operate acoustical testing equipment; inspect space-shuttle components for defects; manufacture telescope lenses and spacecraft windows; and build, operate, and maintain high-precision instruments that must be constantly changed and evolved to meet state-of-the-art designs. Successful technicians are adaptable, attentive to detail, and welcome the challenge posed by state-of-the-art equipment.

Technical communicators. Technical communicators enjoy developing prose and artwork for books, magazines, newspapers, radio and television, brochures, and advertisements.

Technical communicators in the aerospace field must be able to understand complex scientific and technical information in order to select the right phrases and artwork to explain these concepts to others.

Crew members. Crew members must enjoy piloting air- and spacecraft and performing scientific or technical investigations or operating specialized equipment.

Crew positions are commander, pilot, mission specialists, and payload specialist. The commander and pilot fly the craft. A mission specialist is normally a craft-proficient crew member who is also skilled in payload operations. One to four payload specialists are assigned to a flight, depending on the payload. Payload specialists assist the mission specialist in payload operations.

ASSIGNMENT SHEET 2

Exercise **Determine occupational and career-interest areas of choice**

Directions Your goal in this exercise is to get enough general job information so that you can determine the occupational and career-interest areas you wish to explore in the aerospace industry—Steps 2 and 3 in the career decision-making process. To do so, review the notes you have taken on the occupational and career-interest areas discussed in the introduction to this assignment sheet. Then compare these notes to the personal information you gathered in Assignment Sheet 1. Discuss your notes and personal inventory with someone whose opinion you respect and then complete the following exercise.

1. From what you know about the occupational areas in the aerospace industry and from what you have learned about yourself, the occupational area in which you are most interested is? (Rank interest on a scale of from 1 to 4.)

   ______ Communication

   ______ Construction

   ______ Manufacturing

   ______ Energy, power, and transportation

2. From what you know about the career-interest areas in the aerospace industry and from what you have learned about yourself, the career-interest area in which you are most interested is? (Rank interest on a scale of from 1 to 5.)

   ______ Scientist

   ______ Engineer

   ______ Technician

   ______ Technical communicator

   ______ Crew member

3. My occupational area of choice is ____________________

   ____

4. My career-interest area of choice is __________________

   ____

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

ASSIGNMENT SHEET 3—GATHER SPECIFIC JOB INFORMATION

Name ____

Introduction

Step 4 in the career decision-making process is gathering specific job information about the jobs in the occupational and career-interest areas you have chosen to explore within the aerospace industry. Finding job information is easier than you might think. You can gather information by reading printed materials or by going through a computerized job search. Each of these sources of information are discussed below.

Printed materials

Government publications such as the *Occupational Outlook Handbook*, *Dictionary of Occupational Titles*, and the *Guide for Occupational Exploration* are excellent source materials for finding information about specific jobs.

Occupational Outlook Handbook. The *Occupational Outlook Handbook* (OOH) is published by the U.S. Department of Labor and includes general information on approximately 200 occupations. The handbook provides information about job duties, working conditions, level and places of employment, education and training requirements, advancement possibilities, job outlook, earnings, and related occupations.

You should begin your job-information search in this publication by reading the section titled "How To Get the Most From the Handbook" and then browse through the table of contents, where related occupations are grouped in clusters, or look in the alphabetical index for occupations that interest you.

The numbers in parentheses that appear just below the title of most occupational statements in the OOH are called *DOT* codes. DOT stands for *Dictionary of Occupational Titles*, another Department of Labor publication. Each DOT number classifies jobs by the type of work, required training, physical demands, and working conditions. DOT numbers are included in the OOH because some career-information centers and libraries used them for filing occupational information. An index in the OOH cross-references the DOT numbers to occupations covered in the OOH.

Dictionary of Occupational Titles (DOT). The *Dictionary of Occupational Titles* defines and classifies approximately 20,000 occupations performed in the United States economy. The DOT groups jobs into occupations based on their similarities. It also defines the job characteristics of all listed occupations. An occupational definition in the DOT normally has six basic parts.

ASSIGNMENT SHEET 3

Each part represents information about a job in a systematic fashion. The parts are (1) a nine-digit occupational code number (DOT code), (2) the occupational title, (3) the industry or industries in which the occupation is found, (4) other titles by which the occupation also may be known, (5) a description of the tasks performed, and (6) related occupations.

Guide for Occupational Exploration (GOE). The *Guide for Occupational Exploration* is a U.S. Employment Service publication designed to provide you with information about fields of work that match your own interests and abilities. The GOE organizes occupational descriptions into 12 interest areas, 66 work groups, and 348 subgroups. Each description contains a general overview of the occupational area, followed by sections that answer the following questions:

- What kind of work would you do?
- What skills and abilities do you need for this kind of work?
- How do you know if you would like or could learn to do this kind of work?
- How can you prepare for and enter this kind of work?
- What else should you consider about these jobs?

The three government publications described may scare you at first because they are large. But these books are probably the most well-known and often-used sources of occupational information available, and with a little practice and help from your school librarian or counselor, they can become your most valuable career-information tools.

Books and magazines. Many school- and public-library collections include sections of current career information in the form of pamphlets, newspapers, books, and magazines. Most of these small career-information publications are published by the federal government or by the state where you live. Ask your school or local librarian to help you locate this helpful information.

Computerized guidance programs

Your school library or guidance center may have a computerized guidance program. Most computerized programs are self-paced, fun to do, and contain much information about many types of jobs. If such a program is not available in your school, ask your vocational teacher to check into the vocational guidance information available in your state. For example, in Oklahoma, career information can be obtained through the computerized system provided by the Career Search division at the Oklahoma Department of Vocational and Technical Education in Stillwater, Oklahoma. See examples of the printouts provided by this service in Student Supplement 1, "Career Search Booklet." Similar programs are available in other states.

ASSIGNMENT SHEET 3

What you want to know

Before you start gathering specific job information about the aerospace industry, you should review your lists of skills, aptitudes, and other personal information you gathered in Assignment Sheet 1. Keep this information handy as you gather job information. Refer to it whenever you need to refresh your memory about your needs. Remember, you are gathering job information to find a career that fits *you*.

Next, use a standard form for gathering information about specific jobs. By using a standard form, you can easily compare and evaluate the jobs you research.

The following are the topics you will want to include on the standard form you use for job research.

- The nature of the occupation (job duties)
- Working conditions
- Any worker requirements (things you should like and things you should be able to do) on the job
- Typical earnings and opportunities for advancement
- Your chances for employment in the job and the employment outlook for the job
- The educational and training required for success on the job

Exercise **Complete job report forms**

Directions

Your goal in this exercise is to complete Step 4 in the career decision-making process: to gather and compare specific information on jobs in the occupational and career-interest areas you have chosen to explore in the aerospace industry. To do so, you will make five copies of Student Supplement 2, "Job-Information Report Form," research five jobs, and fill out one report form for each job researched.

Turn in your five report forms to your instructor when complete.

INTRODUCTION TO THE CAREERS
IN THE AVIATION AND SPACE INDUSTRY
UNIT I

ASSIGNMENT SHEET 4—MAKE CAREER DECISION

Name ____

Introduction

Making a career decision is Step 5 is the career decision-making process. It is important that you learn to make good decisions in all areas of your life. But learning to make good decisions in some areas of your life can even be critical.

Choosing a career is a very complex decision that presents you with many options and will ultimately affect many areas of your life. Because of this, you should take a great deal of time and care in reviewing and coming to a final career decision.

Remember though, that decision-making is a skill, and like any other skill you get better at it through practice. Many of the career areas you are exploring in the aerospace industry are also seen in other industries. So the decision-making skills you are practicing now will carry over into other fields. And even if you should decide the aerospace industry is not for you, you will still profit from the decision-making skills you have practiced in this exercise.

Exercise

Job comparison

Directions

Your goal in this exercise is to select a career goal—one job from the five jobs you gathered specific information about in Assignment Sheet 3. To do so, you will consider your five options by completing the following steps.

Write a checkmark in the blank before each step below as you complete it.

______1. Look at the information you have gathered on each of the five "Job-Information Report Forms" you filled out in Assignment Sheet 3. Then try to imagine as clearly as possible what it would be like to actually be working at each of these jobs. Think of the advantages and disadvantages of each job. Try to imagine which job seems to best meet your needs.

______2. Complete Student Supplement 3, "Job-Comparison Worksheet."

- In the boxes under the column headed "Job Choices," list the five jobs you reported on in Assignment Sheet 3.
- In the boxes under the column headed "Advantages," list beside each job choice the advantages you imagine each job would have.

ASSIGNMENT SHEET 4

- In the boxes under the column headed "Disadvantages," list beside each job choice the disadvantages you imagine each job would have.

_____3. Carefully review Student Supplement 3, and try to decide which choice seems to have the best chance of meeting your personal needs. Then on the blanks below, rank the five jobs you have explored.

Career goal—First choice ____________________

____

Second choice ____________________

____

Third choice ____________________

____

Fourth choice ____________________

____

Fifth choice ____________________

____

INTRODUCTION OF THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

ASSIGNMENT SHEET 5—DEVELOP PLAN OF ACTION TO MEET CAREER GOAL

Name ____

Introduction

We all have good intentions of meeting the career goals we have set for ourselves. But we don't always develop objectives and set timeframes for meeting our goals. We become procrastinators—people who put things off.

By learning to develop objectives and set timeframes for meeting goals, you develop a career plan of action. You help yourself get out of the habit of putting things off. You learn to do things when they need to be done.

Career *objectives* are specific actions or steps you will take to meet your career goal. Three factors should be taken into account when you determine your career objectives:

- The level of education and training you will need to meet your career goal.
- Money you may need for education or equipment.
- Jobs leading to your career goal.

There are two timeframes for taking action on the objectives you plan to achieve: short-term and long-term. A *short-term objective* is any objective you can accomplish in a year's time. An example of a short-term objective could be to complete this course. A *long-term objective* is one that takes more than a year's time to complete. An example of a long-term objective could be to graduate from high school. Another example could be to become an aerospace engineer.

Exercise **Personal career plan of action**

Directions

Take out the information you gathered on the career of your choice. Also locate Student Supplements 4 through 8. Then complete each of the following steps.

Write a checkmark in the blank before each step as you complete it.

______1. At the top of Student Supplement 4, "Career Objectives," write down your career choice. Then, using the job information you gathered, list under the proper heading the education and training you will need, money you may need for your education and training or equipment, and jobs leading to your ultimate career goal. Don't worry about putting the lists in order yet. Just write down everything that will lead you toward your career goal. These lists become your career objectives.

ASSIGNMENT SHEET 5

_____2. Take out Student Supplements 5, 6, and 7 and the list of objectives you completed on Student Supplement 4.

- On Student Supplement 5, "What You Can Do This Year," make a list of your short-term objectives. Select short-term objectives from Student Supplement 4 and sort and list these under the proper heading on Student Supplement 5.
- On Student Supplement 6, "What You Can Do in High School," make a list of your long-term objectives that can be completed while you are in high school. Select these objectives from Student Supplement 4 and sort and list these under the proper heading on Student Supplement 6.
- On Student Supplement 7, "What You Can Do After High School," make a list of the long-term objectives you will complete after you graduate from high school. Select these objectives from Student Supplement 4 and sort and list these under the proper heading on Student Supplement 7.

_____3. Go back over Student Supplements 5, 6, and 7 and assign dates to each objective. For short-term objectives, you should be able to list exact dates. For long-term objectives, you may only be able to estimate the year.

Once you have assigned dates and estimated years to complete each objective, you may see that some of your objectives interfere with one another. If this happens, make adjustments, or if adjustments cannot be made, you will have to decide which objective is more important.

Remember, you should review and revise your career plan of action as needed in the future. Your career plan is not carved in stone. Make it flexible. But try not to change it for foolish reasons. Think about what you are doing.

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

ASSIGNMENT SHEET 6—EXPLORE THE INTERRELATIONSHIP OF THE OCCUPATIONS IN THE AVIATION AND SPACE INDUSTRY

Name ______________________________ Score ______________

Introduction

Thus far in this unit, you have studied the occupational areas (Information Sheet, Objective 2) and the career-interest areas (Objective 3) of the aerospace industry. You have also studied in a general way (in Objective 5) the interrelationship of the occupational areas in the aviation and space industry. And, as a result of the notes you took in Assignment Sheet 2 and the research you did in Assignment Sheets 1 through 5, you should be much more aware of the work performed in these areas. Now you should be able to successfully explore the worker interrelationships in a specific way.

Your goal in the exercise included in this assignment sheet is to learn more about the how the workers in various areas of the aerospace industry work together to complete a mission. To do so, you will, first, review Student Supplement 1, "Career Search Booklet" and the information you have studied in Assignment Sheets 1 through 5. Second, you will read Student Supplement 9, *NASA Facts*, "Life Aboard the Space Shuttle," and then write descriptions of how you believe the various workers might have cooperated to complete their mission—designing and constructing the crew cabin of the Space Shuttle.

Exercise

Descriptions of the interrelationship of the various workers in the aerospace industry

Directions

Read Student Supplement 9, *NASA Facts*, "Life Aboard the Space Shuttle," and then, under each of the following headings, write a short description of how you believe the various workers would have cooperated to complete their mission of designing and constructing the crew cabin of the Space Shuttle.

1. Living accommodations ______________________

____

____

____

____

____

ASSIGNMENT SHEET 6

2. Air

3. Menu

ASSIGNMENT SHEET 6

____

4. Sanitation ______________________________

5. Space suits ______________________________

6. Recreation and sleep ______________________________

ASSIGNMENT SHEET 6

7. Weightlessness

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

ASSIGNMENT SHEET ANSWERS

Assignment Sheet 1 through Assignment Sheet 5

Evaluated to the satisfaction of the instructor

(EVALUATOR'S NOTE: Please notice that there is no score line at the beginning of these assignment sheets. The content of personal opinions requested of the student in the assignments sheets should not be graded per se; there are no right or wrong answers. In evaluating these assignment sheets, the evaluator should look for seriousness of effort and completeness rather than for "correctness.")

Assignment Sheet 6

Evaluated to the satisfaction of the instructor

(EVALUATOR'S NOTE: The following information can be used by the instructor in evaluating the various sections of the exercise in this assignment sheet.)

- **Physicist and astronomer**—Work with engineers to determine physical properties of materials that are used in the cabin area of the Space Shuttle; work with computer programmers to develop tables and charts for navigational purposes
- **Meteorologist**—Works with astronomers and computer programmers to develop long-range weather forecasts to help predict optimum conditions for take-off and landing
- **Biological scientist**—Plans and designs the mid-deck to help lessen the change in environmental factors and abnormal living conditions experienced by astronauts while they are in flight; conducts biological experiments and flight experiments
- **Physician**—Designs medical kit for Shuttle
- **Psychologist**—Works with biological scientists to design mid-deck to lessen psychological stress experienced by crew while they are in flight
- **Dietitian and nutritionist**—Design and prepare special in-flight diet for each crew member
- **Computer programmer**—Writes the programs used in the computers on the flight deck and mid-deck of the crew cabin; "debug" computer errors, rewrite programs to produce desired results, and modify existing programs
- **Computer systems analyst**—Tests the flight-deck and mid-deck computers to be sure they operate correctly

ASSIGNMENT SHEET ANSWERS

- **Aerospace engineer**—Designs crew cabin and tests ability of the Space-Shuttle crew cabin to withstand structural stress; supervises the performance testing of Space-Shuttle crew cabin
- **Chemical engineer**—Designs and develops heat-transferring panels used on outside of Space-Shuttle crew cabin to protect crew from heat of reentry; mixes and develops special glue that holds panels on Shuttle surface; designs the radiator system and the system for keeping the mid-deck cool
- **Biomedical engineer**—Designs life-support systems for the flight deck, such as oxygen system, waste-removal system, and airlock system; plans location of medical equipment
- **Electrical and electronics engineer**—Determine specifications for Shuttle power system and lighting system; wire and maintain integrity within control panels
- **Industrial engineer**—Supervise the building, inspection, and engineering of the crew cabin; inspect tools and machines to determine that safety standards are maintained
- **Mechanical engineer**—Designs foot-restraint platform used on the flight deck; designs operational seats for the commander and pilot
- **Metallurgical and materials engineer**—Conducts research and develops appropriate materials for specialized components required in crew cabin (for example, new alloys or metals for the instrument panel, materials for windows, flooring, seating, and sleeping areas)
- **Engineering technician**—Assists engineer in developing and testing processes such as testing the Shuttle electrical systems, the side-hatch egress, escape-panel systems, and door latches and locks
- **Aircraft mechanic**—Tests, repairs, and/or replaces Shuttle instruments on instrument panel
- **Welder**—Joins the metal parts of the Space Shuttle crew cabin and the metal parts for the seat frames
- **Metal/plastic-working machine operator**—Operates machines (lathes, molding machines, and shapers) used to make crew-cabin components such as storage facilities, sleeping bunks, instrument panels, and food containers

ASSIGNMENT SHEET ANSWERS

- **Writer and editor**—Writes and modifies manuals used for various operations
- **Visual artist**—Draw precise illustrations of flight deck and mid-deck to compare the efficiency of several different set-ups
- **Astronaut**—Manipulates components designed and built by all the other workers in order to fly Shuttle and conduct experiments to complete Shuttle mission

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

WRITTEN TEST

Name ______________________________ Score ______________

1. Match terms associated with careers in the aviation and space industry to their correct definitions. Write the correct numbers on the blanks.

______a. Personal judgment concerning the importance or worth of a thing or quality

______b. Planned or responsible activity a person performs with expectation of return for efforts

______c. Path person follows within occupational area

______d. Group of jobs similar according to interests; work activity occurring in all occupational areas

______e. Thing, subject, or activity in life that you like to do or that makes you happy

______f. Talent or potential for being able to do something

______g. Activity you have been trained to do and have practiced doing

______h. Group of jobs similar according to the nature of the work being performed

______i. Industry involved with the design, construction, manufacture, or flight of an aircraft, satellite, or space vehicle

1. Aviation and space industry
2. Job
3. Occupational area
4. Career
5. Career-interest area
6. Interest
7. Aptitude
8. Skill
9. Value

WRITTEN TEST

2. Match occupational areas in the aviation and space industry to their correct definitions. Write the correct numbers on the blanks.

______a. Jobs involved with changing information into messages that can be transmitted

______b. Jobs involved with converting energy into mechanical, fluid, and electrical power

______c. Jobs involved with using raw materials and processes to produce products that are used elsewhere

______d. Jobs involved with using manufactured goods and materials to build structures on site

1. Communication
2. Construction
3. Manufacturing
4. Energy, power, and transportation

3. Match career-interest areas in the aviation and space industry to their correct definitions. Write the correct numbers on the blanks.

______a. People whose job interests include studying how the universe operates, observing the natural world, creating hypotheses to explain their studies and observations, and then carrying out experiments to validate their hypotheses

______b. People whose job interests include applying physical and mathematical principles to solve specific real-world problems

______c. People whose job interests include piloting air- and spacecraft and performing scientific or technical investigations or operating specialized equipment

______d. People whose job interests include developing prose and artwork for books, magazines, newspapers, radio and television, brochures, and advertisements

______e. People whose job interests include building, operating, and maintaining the complex equipment that bring engineers' designs to life

1. Scientists
2. Engineers
3. Technicians
4. Technical communicators
5. Crew members

WRITTEN TEST

4. List steps in career decision making.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

   e. ______________________________

   f. ______________________________

   g. ______________________________

5. Describe the interrelationship of the occupational areas in the aviation and space industry.

   a. Communication ______________________________

   ____

   ____

   ____

   b. Construction ______________________________

   ____

   ____

   ____

   c. Manufacturing ______________________________

   ____

   ____

   ____

   d. Energy, power, and transportation ______________________________

   ____

   ____

   ____

INTRODUCTION TO THE CAREERS IN THE AVIATION AND SPACE INDUSTRY
UNIT I

WRITTEN TEST ANSWERS

1. a. 9
   b. 2
   c. 4
   d. 5
   e. 6
   f. 7
   g. 8
   h. 3
   i. 1

2. a. 1
   b. 4
   c. 3
   d. 2

3. a. 1
   b. 2
   c. 5
   d. 4
   e. 3

4. a. Gather personal information
   b. Gather general job information
   c. Identify occupational area of choice and career-interest area of choice
   d. Gather specific job information to compare jobs within occupational area of choice and career-interest area of choice
   e. Make career decision
   f. Develop plan of action to meet career goal
   g. Evaluate career goal and plan of action

5. a. Provides the exchange of information required between occupational areas for the efficient operation of manufacturing plants, construction sites, and transportation systems
   b. Builds structures to house manufacturing and communication enterprises; to produce, store, and transmit power; and to transport materials and products
   c. Produces products and processes used in the other three occupational areas
   d. Produces, stores, and transmits power used in manufacturing, construction, and communication; moves materials and products used by manufacturing, construction, and communication

SATELLITE COMMUNICATION SYSTEMS
UNIT II

UNIT OBJECTIVE

After completing this unit, the student should be able to define the stages and describe the forms of interference in a basic communication system, and apply these definitions and descriptions in creating an interference-free message and in conducting a satellite-communication simulation activity. The student will demonstrate these competencies by completing the assignment sheet, lab activity sheet, and written test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. State definitions of the terms *communication* and *interference*.
2. List and define the stages of a basic communication system.
3. Describe forms of interference that can occur at various stages in a basic communication system.
4. Discuss the importance of feedback in a basic communication system.
5. Define parts of the process in a basic communication system.
6. Describe the parts of the process in a satellite communication system.
7. Describe the parts of the process in a helium-neon laser communication system.
8. Practice constructing an interference-free message. (Assignment Sheet 1)
9. Use a laser to simulate satellite communication. (Lab Activity Sheet 1)

SATELLITE COMMUNICATION SYSTEMS
UNIT II

SUGGESTED ACTIVITIES

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review teaching suggestions given in the "Delivery and Application" section and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the "Suggested Resources" section.

- Prepare classroom and lab. Put up posters, charts, and signs. Display articles related to the objectives of this unit, such as *Sentinels in the Sky: Weather Satellites*.

- Carefully review Assignment Sheet 1 and locate all the materials needed to complete this assignment. Read Teacher Supplement 1, "Illustrations to Be Used in Assignment Sheet 1," and develop other drawings to go along with the assignment sheet as needed.

- Carefully review Lab Activity Sheet 1, "Use a Laser to Simulate Satellite Communication," and Teacher Supplement 2, "Laser Classifications and Power Ratings," to determine the laser specifications and all the materials needed to complete this laser communication activity. Display signs concerning laser safety in the lab. Use Teacher Supplement 3, "Laser Caution Sign," as a master for creating these safety signs for the classroom.

Delivery and Application

Unit introduction

- Provide students with objective sheet. Discuss unit and specific objectives.

- Read to students Teacher Supplement 4, "Houston, We've Got a Problem." Use this supplement to emphasize the importance of something as basic as good communication in the complex high-tech world of the space industry.

- Provide students with information sheet. Discuss information sheet.

SUGGESTED ACTIVITIES

Objective 1 State definitions of the terms *communication* and *interference*.

Objective 2 List and define the stages of a basic communication system.

Objective 3 Describe forms of interference that can occur at various stages in a basic communication system.

- Treat these three objectives as a unit that reviews the basic communication system and the forms of interference that can occur to block effective communication. Discuss with students how the input, process, and output stages are evident in all communication systems—from simple face-to-face discussion to satellite communication. Also discuss how interference can occur in all communication systems—from simple face-to-face discussion to satellite communication.

- Conduct a communication activity to illustrate input, process, output, and interference.

  Divide the class into groups of three. Label one person in each group "Input," "Process," and "Output." Place the three group members in chairs one beside the other.

  Tell the group members that during the communication activity, the "Input" person will read a message to the "Process" person, who will in turn relay the message to the "Output" person. The "Input" person will read the message only one time. The "Process" person will not record the message, but will repeat the message from memory. The "Process" person will not be allowed to question the "Input" person or ask for clarification in any way. The "Output" person will not be allowed to question the "Process" person or ask for clarification in any way.

  Provide the "Input" person in each group with a written message that has been purposely poorly written to be an example of an interference-laden message.

  Instruct the "Input" person to read the message to the "Process" person. Tell the student not to shout during the reading of the message, but to read the message in a normal voice.

  Provide a source of noise, such as loud music, that will be played when the "Input" person attempts to repeat the message to the "Process" person.

SUGGESTED ACTIVITIES

The "Process" person will not record the message on paper but will pass the message as he or she remembers it to the "Output" person. Again remind the "Process" person not to shout, but to repeat the message in a normal voice and to repeat the message only once.

Provide the "Output" person with a pencil and paper where he or she will record the message received. Have students compare the message received and recorded to the message sent.

Discuss with students the sources of interference in the activity they just performed: the poorly written message and the noise occurring during transmission. Discuss the fact that interference often occurs during the process stage and emphasize the importance of beginning with a message that is as interference-free as possible.

- Read with students the introduction and directions to Assignment Sheet 1, "Practice Constructing an Interference-Free Message." Also discuss with students the proper use of Student Supplement 1, "Final Draft of Step-by-Step Duplication Procedure."
- Have students complete Assignment Sheet 1.

Objective 4 Discuss the importance of feedback in a basic communication system.

- Read with students the three statements made in the information sheet. Expand these statements to promote a discussion of how feedback is used to close the loop in a basic communication system.
- To illustrate the importance of feedback, hand out new messages to the three-person groups and then repeat the communication activity discussed above, but this time let "Input," "Output," and "Process" ask each other questions to clarify the message. Then compare the two written messages; the message recorded by the "Output" person should now be much closer to the original message.

Objective 5 Define parts of the process in a basic communication system.

Objective 6 Describe the parts of the process in a satellite communication system.

SUGGESTED ACTIVITIES

Objective 7 Describe the parts of the process in a helium-neon laser communication system.

- Treat these three objectives as a unit to relay the idea that all forms of communication systems contain the same process components: a transmitter, a channel, and a receiver. Discuss the definitions of these three components as presented in the basic communication model presented in Objective 5, and then discuss the corresponding components in satellite and laser communication as presented in Objectives 6 and 7.

- Relate to students that these concepts are important because they will help the student understand the relationships between satellite communication and the laser simulation activity they will be performing in Lab Activity Sheet 1.

- Relate to students the safety rule of knowing the parts of any type of equipment with which they will be working before they begin working with it. Display the laser you will be using in the lab and point out the laser power switch, power cord, microphone jack, and open/close clip. Discuss the proper use of each part, stressing the safety factor associated with the open/close clip.

  Display the receiver you will be using in the lab and point out the receiver power switch, audio switch, speaker, and photodiodes. Demonstrate and discuss the proper use of each part.

- While you supervise, allow students to examine the laser and the receiver.

- Take the students to the lab and set up the laser, mirror, and receiver as shown in the diagrams Lab Activity Sheet 1. Demonstrate the transmission of sound, stressing safety rules to be followed.

- Read with students and discuss the introduction to Lab Activity Sheet 1 and discuss the use of Student Supplement 2, "Message Record Form," and Student Supplement 3, "Interference Record Form." Have students make extra copies of these forms in case they find it necessary to complete more than one transmission activity before all forms of interference have been eliminated.

- Have students complete Lab Activity Sheet 1.

SUGGESTED ACTIVITIES

Evaluation

- Give written test.
- Compile written-test, assignment-sheet, and lab-activity-sheet scores.
- Reteach and retest as required.

Suggested Resources

Resources used in developing unit

Print media

- Balistreri, Jerry, ed. *Laser Technology*. Salt Lake City, Utah: Utah State Board for Vocational Education, July 1985.
- Gottlieb, Herbert H., ed. *101 Ways to Use a Laser Plus Some More Just for Fun*. Bellmawr, New Jersey: Metrologic Instruments, Inc., 1987.

  The two sources listed above contain numerous activities to be used with a Class II laser, which is safe for classroom use. The activities listed in the second of the two sources above are quick thumbnail sketches of various ways to use a laser in the classroom. These sketches are presented to stimulate the instructor's interest in creating lab activities using a laser. Much work would still be required by the instructor to develop the activities into a complete learning experience.

  The activities listed in the first source were compiled for use by the Technology Education instructors in Utah. Metrologic Instruments, Inc., assisted with the project. The book contains 15 learning activity packets, beginning with laser theory and safety including several laser experiments, and concluding with laser careers. The laser experiments are much more developed into a complete learning experience; however, the listing is much more limited than in the previously mentioned source.

- *Laser—Technology Education Learning Activity Package*. Stillwater, Oklahoma: Oklahoma Department of Vocational and Technical Education, Technology Education Division, n.d.

  This laser module consists of 10 learning activities. Each activity has associated information the student must read in order to complete the activity successfully. The module also contains a list of reference books for additional sources of laser information.

SUGGESTED ACTIVITIES

The following is a listing of some of the activities included in the LAP: "Measuring Distance with a Laser," "Measuring Angle of Reflection," "Laser Light Show," "Data Transmission on a Light Beam."

Resources to be used to supplement unit materials

Print materials

- Haynes, Robert. *NASA Facts: Sentinels in the Sky: Weather Satellites*. National Aeronautics and Space Administration and the National Oceanic and Atmospheric Administration (NOAA), n.d.

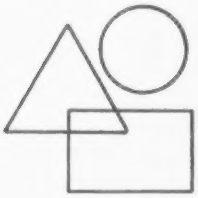
  Although the emphasis of this publication is on weather satellites, the 17-page booklet does discuss other types of satellite applications including communication. The line art and photographs included in the booklet are spectacular and the layout of the publication quite interesting and appealing. The booklet also includes a short glossary of terms that might need to be explained to students.

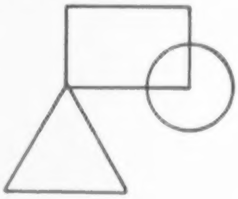
SATELLITE COMMUNICATION SYSTEMS
UNIT II

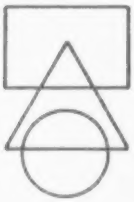
TEACHER SUPPLEMENT 1—ILLUSTRATIONS TO BE USED IN ASSIGNMENT SHEET 1

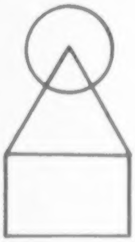
Directions

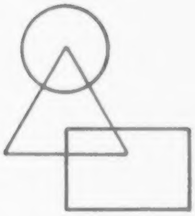
The instructor will insert one of the following illustrations where indicated in Assignment Sheet 1. The students will use these illustrations in writing a step-by-step procedure for duplicating an illustration. If you need more than the eight illustrations shown here, you will find it easy to create similar drawings to be used with the assignment sheet.

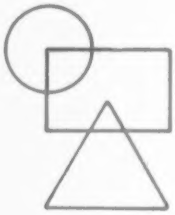


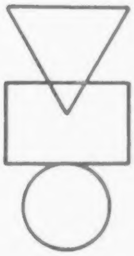


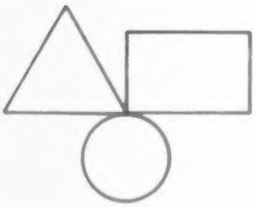












SATELLITE COMMUNICATION SYSTEMS
UNIT II

TEACHER SUPPLEMENT 2—LASER CLASSIFICATIONS AND POWER RATINGS

General laser information

Lasers are classified into four major categories. Class I, Class II, Class III, and Class IV. Laser classifications are based on the output power of a laser's beam. The power of the laser beam is measured in milliwatts (mW).

Class I lasers are those that generate such a low-powered beam that they cannot cause damage to anyone or anything. People can look directly into a Class I laser all day without any damage to their eyes. Supermarket checkout scanning systems and video disk readers are examples of Class I lasers.

Class II lasers are those that generate a visible beam with a power rating **not** exceeding 1 mW (one thousandth of a watt). Most helium-neon lasers used in classroom demonstrations are Class II lasers; therefore, Class II lasers are often called "demonstration lasers." These lasers are required to have a warning label, a protective housing, an indicator to show when the power is on, and a method to block the beam without turning off the power. These lasers will have a yellow **CAUTION** sign on them that warns the user not to stare directly into the beam.

Class III lasers produce enough power to be dangerous to a person's eye. The beam from a Class III laser can cause eye damage before the blink reflex can block the beam. The damage could result in small blind spots in the person's vision. These lasers are labelled with a red and white **DANGER** sign warning people to avoid getting the direct beam into the eye. They also have a key-activated master switch and a delay mechanism to help prevent accidential exposure to the laser beam.

Class IV lasers produce serious eye damage even from scattered reflections of the beam. These lasers will also produce serious skin burns if a person is exposed to the beam. The person operating a Class IV laser must take precautions to avoid being hurt. He or she must use special glasses to protect the eyes and direct the beam to a safe target area. When Class IV lasers are used to cut or weld metals, or for other applications, they are usually enclosed by a cabinet so that people cannot be exposed to the beam. When enclosed in a cabinet, the laser is safe to use without eye or skin protection. Class IV lasers exceed 5 mW power output.

For information concerning federal laser-safety regulations, write:

U. S. DHEW Bureau of Radiological Health
5600 Fishers Lane
Rockville, Missouri 20852

Specifications for the laser to be used in Lab Activity Sheet 1

The laser used in Lab Activity Sheet 1 should be a Class II laser that is modulated to transmit audio signals.

TEACHER SUPPLEMENT 2

Purchasing information

Lasers may be ordered from the following companies, although this is not a complete listing of laser manufacturers.

- Carolina Biological Supply Company
  2700 York Road
  Burlington, North Carolina 27215

  Phone: 1-800-334-5551

- Carolina Biological Supply Company
  Box 187
  Gladstone, Oregon 97027

  Phone: 1-800-547-1733

- Fisher-Scientific
  Educational Materials Division
  4901 West LeMoyne Street
  Chicago, Illinois 60651

  Phone: 1-800-621-4769

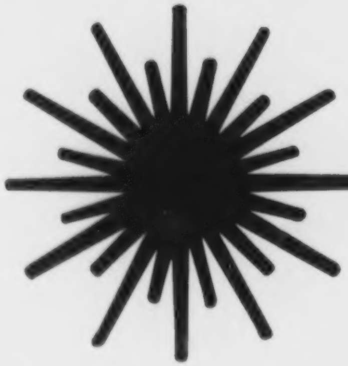
Approximate prices for lasers

Class II lasers will cost between $340 and $400. Accessories for lasers will cost extra and prices range from $5.90 for a pair of lenses to $410 for a complete optics bench system.

SATELLITE COMMUNICATION SYSTEMS
UNIT II

TEACHER SUPPLEMENT 3—LASER CAUTION SIGN

CAUTION



HELIUM NEON LASER

DO NOT STARE INTO BEAM

Courtesy of Roger Stacy, State Supervisor of Technology Education, Stillwater, Oklahoma.

SATELLITE COMMUNICATION SYSTEMS
UNIT II

TEACHER SUPPLEMENT 4—HOUSTON, WE'VE GOT A PROBLEM

Without precise and efficient communication between the crew and Mission Control, the three astronauts aboard Apollo 13 would not have survived the return trip.

As Captain James Lovell, commander of the ill-starred Apollo 13 mission, described it: "Fred [Haise, the lunar module pilot] was still in the lunar module. Jack [Swigert, pilot of the command module] was back in the command module in the left-hand seat and I was halfway in between the lower equipment bay wrestling with TV wires and a camera—watching Fred come on down—when all three of us heard a rather large bang—just one bang. Now, before that . . . Fred had actuated a valve that normally gives us that same sound. Since he didn't tell us about it, we all rather jumped up and were sort of worried about it; but it was his joke and we all thought is was a lot of fun at the time. So when this bang came, we really didn't get concerned right away . . . but then I looked up at Fred . . . and Fred had that expression like it wasn't his fault. We suddenly realized that something else had occurred . . . but exactly what we didn't know."

Haise said he felt a vibration. Up in the command module, Swigert reported, ". . . about 2 seconds elapsed when I had a master alarm and a main bus 'B' undervolt [i.e., a loss of power] . . . I transmitted to Houston that we had a problem."

Lovell continued: ". . . My concern was increasing all the time. It went from 'I wonder what this is going to do to the landing' to 'I wonder if we can get back home again' . . . and when I looked up and saw both oxygen pressures . . . one actually at zero and the other one going down . . . it dawned on me that we were in serious trouble."

Lovell's assessment was accurate and, if anything, conservative. The bang he heard was the explosion of the second liquid oxygen tank in the service module (SM). This tank provided the vital oxygen on which fuel cells 1 and 2 relied to generate the electric power to operate the systems in the command and service module (CSM). The fuel cells were Apollo's primary power source. There was a backup battery-powered electric supply in the CSM with a lifetime of as much as 10 hours. Under ideal circumstances, Apollo 13, at the time of the explosion, was 87 hours from home.

Emergency in space

The nature and dimensions of the emergency were starkly evident to the crew and to the Mission Control Center. Lovell and his crewmates were more than 200,000 nautical miles out in space with a dead SM, including its main propulsion engine. The explosion had destroyed the CSM's main supply of life-sustaining oxygen and power. The command module (CM) operating life of 10 hours had to be reserved for the approach to the Earth's atmosphere because, of the three modules, the CM alone had the heat shield that would allow the crew to reenter the atmosphere and splash down safely.

TEACHER SUPPLEMENT 4

The crew's salvation rested with the lunar module (LM). This oddly shaped spacecraft was designed to drop out of lunar orbit after separating from the CSM, land two astronauts gently on the Moon and sustain them while there, and then carry them back to a rendezvous with the mother ship in lunar orbit. However, with the CSM a partial wreck and drifting in space, the LM became the lifeboat. Mission Control aborted the mission and ordered the crew into the LM.

What followed was an epic struggle that pitted the skilled and highly trained professionals in the spacecraft working in close coordination with the ground-based team at the Mission Control Center against the hostile environment of space. For 86 hours and 57 minutes—more than three tension-packed days—the struggle continued.

Mobilizing for the emergency

While the astronauts powered up the LM lifeboat, the Mission Control Center began mobilizing the substantial and varied talents available to help in dealing with the crisis. In addition to the contractor's representatives normally posted in Houston to assist with the flight, Mission Control phoned the manufacturers of the major systems and subsystems in the LM and in the CSM and instructed them to have their top specialists immediately available to help provide hard answers to even harder questions. Thus, the engineers and their simulators and computers at North American Rockwell (Rockwell International) were brought on-line. Experts at Grumman Aerospace Corporation (the LM manufacturer) were alerted as were the experts at TRW Systems who built the descent propulsion engine that would have to supply the thrust to put the spacecraft on the correct return course. A coast-to-coast network of simulators, computers, and experts was quickly hooked up. Their operation provided a tour de force of the breadth and depth of American technological competence.

The problem had two major aspects. One aspect was getting Odyssey and Aquarius, call names for the CM and the LM, respectively, on a true and quick course for home with the decisive factors being propulsion and guidance. The second aspect centered on the consumables—power, oxygen, and water—with the key being conservation.

More problems

The accident and the economies it forced on flight operations created a sequence of problems that kept Mission Control, its teams of experts, and the simulators and computers busy for most of the return trip. The three-module configuration made it necessary to recalculate course corrections and work out new detailed time lines. Maneuvers had to be refigured so that they could be executed with a minimum use of power and water (for cooling equipment). How would the linked LM and CM respond after the SM had been jettisoned? What would be the effect of discarding the LM 1 hour before reentry?

Questions of this kind, and there were many of them, were put through the various simulator and computer complexes until the ground team was certain that all possibilities had been checked out and that the best answers were in hand. Astronauts Alan Shepard and Ed Mitchell were operating one of the LM simulators at the Johnson Space Center in Houston and Astronauts Gene Cernan and David Scott were working in the other LM. At

TEACHER SUPPLEMENT 4

Kennedy, Astronaut Dick Gordon was simulating emergency procedures in a third LM. It is estimated that these simulators were used about 40 hours each during the flight. One team of simulator specialists worked around the clock without a break. No procedure, maneuver instruction, or checklist was relayed to the crew that had not been thoroughly proven.

Ingenuity at work

Some difficulties that arose on the return trip were solved by means of jerryrigs that were marvels of ingenuity. The atmosphere in the spacecraft cabin is "washed" of carbon dioxide (produced by the crew's exhalations) by canisters of lithium hydroxide. The overload on the LM's canister system saturated it and the carbon dioxide in the cabin atmosphere began a potentially dangerous rise.

After studying the problem, Mission Control gave instructions to Lovell on how he could make an adapter that would allow the attachment of a hose to the lithium hydroxide canisters in the CM so that they could be used to purify the air. Lovell improved on the instructions by splicing together two hoses so that the rig would reach through the docking tunnel into the CM. Within an hour, carbon dioxide levels dropped sharply.

The amended reentry procedure called for two course corrections: the first to get the spacecraft more toward the center of the reentry corridor and the second to refine the angle of entry, which had to be between 5.5 and 7.5 degrees. Without the guidance platform powered up, the normal method of determining the attitude of the spacecraft would be by taking star sights. However, since the explosion in the SM, the spacecraft had been shrouded in a cloud of debris that glittered in the sun and made sighting on a star impossible. The Apollo 8 crew had worked out a technique of using the Earth's terminator and the sun. Lovell recounted his reaction at a postflight press conference:

"When the ground read out the procedure to us, I just couldn't believe it. I thought I'd never have to use something as way-out as this. And here I was on Apollo 13, using this very same procedure . . . Because it was a manual burn, we had a three-man operation. Jack would take care of the time. He'd tell us when to light off the engine and when to stop it. Fred handled the pitch maneuver and I handled the roll maneuver and pushed the buttons to start and stop the engine." The burn made the desired refinement in the reentry angle of 6.49 degrees.

A successful failure

By a matchless display of tenacity, resourcefulness, ingenuity, and courage, the determined professionals at Mission Control working in close coordination with a coolly expert crew had averted catastrophe and brought the astronauts through a brush with death.

As an aborted mission, Apollo 13 must officially be classed as a failure, the first in 22 manned flights. But, in another sense, as a brilliant demonstration of the human capability under almost unbearable stress, it has to be the most successful failure in the annals of space flight.

Reprinted with permission from *NASA Facts*, "Apollo 13: A Successful Failure." National Aeronautics and Space Administration, Lyndon B. Johnson Space Center, n.d.

SATELLITE COMMUNICATION SYSTEMS
UNIT II

INFORMATION SHEET

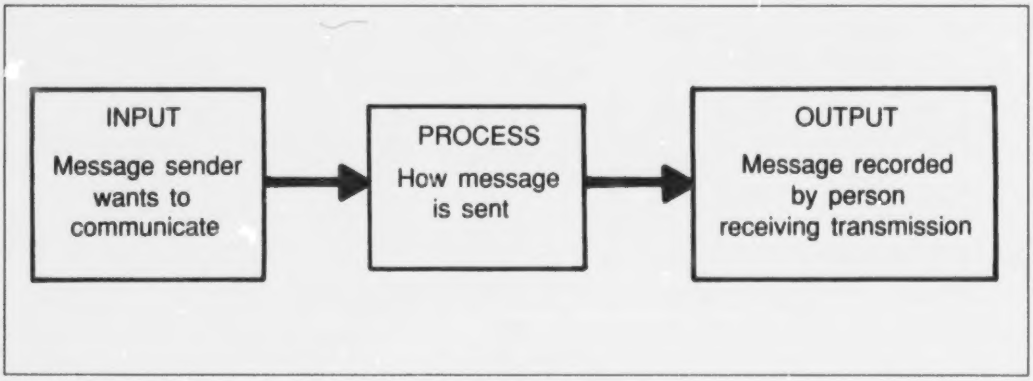
1. **Definitions of the terms *communication* and *interference***

   a. **Communication**—Process by which information is exchanged between individuals or machines through a common system of signs, symbols, or behavior

   b. **Interference**—Anything that blocks the communication process

2. **Stages of a basic communication system and their definitions** (Figure 1)

FIGURE 1


INPUT
Message sender wants to communicate
PROCESS
How message is sent
OUTPUT
Message recorded by person receiving transmission

   a. **Input** (stage 1)—Message sender wants to communicate

   b. **Process** (stage 2)—How message is sent (transmitted)

   c. **Output** (stage 3)—Message actually recorded by person receiving transmission

3. **Forms of interference that can occur at the various stages in a basic communication system**

   a. **Stage 1** (input)—Sender creates poorly constructed message

   b. **Stage 2** (process)—Noise is created during transmission

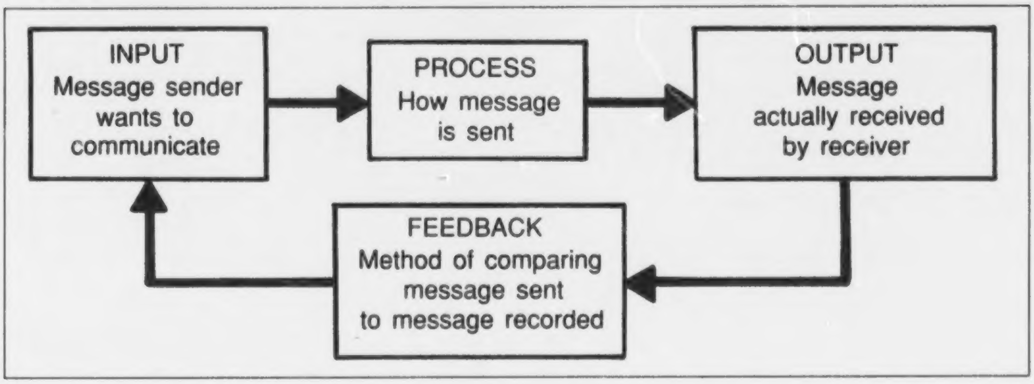
   (NOTE: *Noise* is the term for a special type of interference created during the transmission process. A common example of noise is the static you hear on your radio as a result of the radio transmission process.)

   c. **Stage 3** (output)—Person receiving transmission misinterprets message transmitted or receives poorly constructed message

INFORMATION SHEET

4. **Importance of feedback in a basic communication system** (Figure 2)

FIGURE 2


INPUT
Message sender wants to communicate
PROCESS
How message is sent
OUTPUT
Message actually received by receiver
FEEDBACK
Method of comparing message sent to message recorded

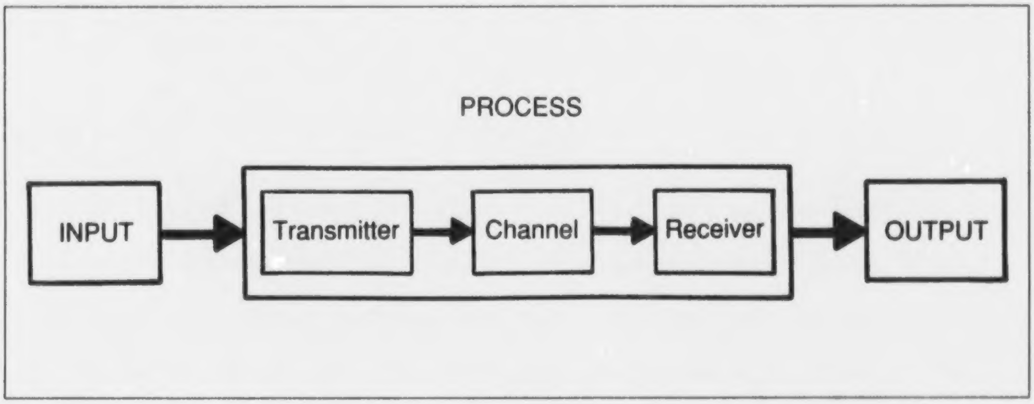
a. *Feedback* is the term used to describe the contact between person receiving transmission and sender

b. Feedback closes loop in basic communication system by providing a way of comparing message sent to message recorded after transmission

c. Feedback tells sender whether person receiving transmission has understood message correctly, and if not, helps sender determine source of interference

5. **Parts of the process in a basic communication system and their definitions** (Figure 3)

FIGURE 3


PROCESS
INPUT
Transmitter
Channel
Receiver
OUTPUT

a. **Transmitter**—Means of transmitting (sending) message

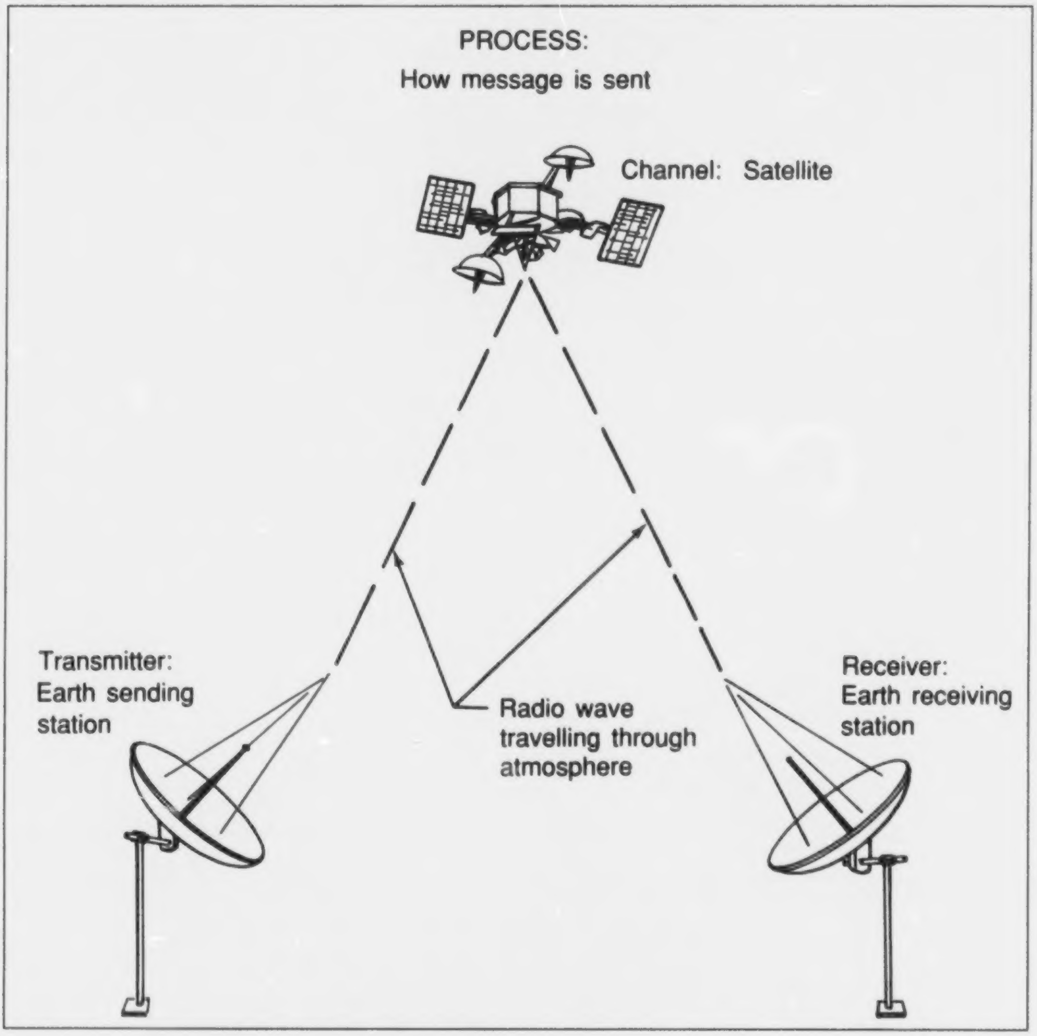
b. **Channel**—Route message takes (transmission)

c. **Receiver**—Means of accepting transmitted message

INFORMATION SHEET

6. **Parts of the process in a satellite communication system and their descriptions** (Figure 4)

FIGURE 4


PROCESS:
How message is sent
Channel: Satellite
Transmitter:
Earth sending station
Radio wave travelling through atmosphere
Receiver:
Earth receiving station

a. **Transmitter**—Earth sending station

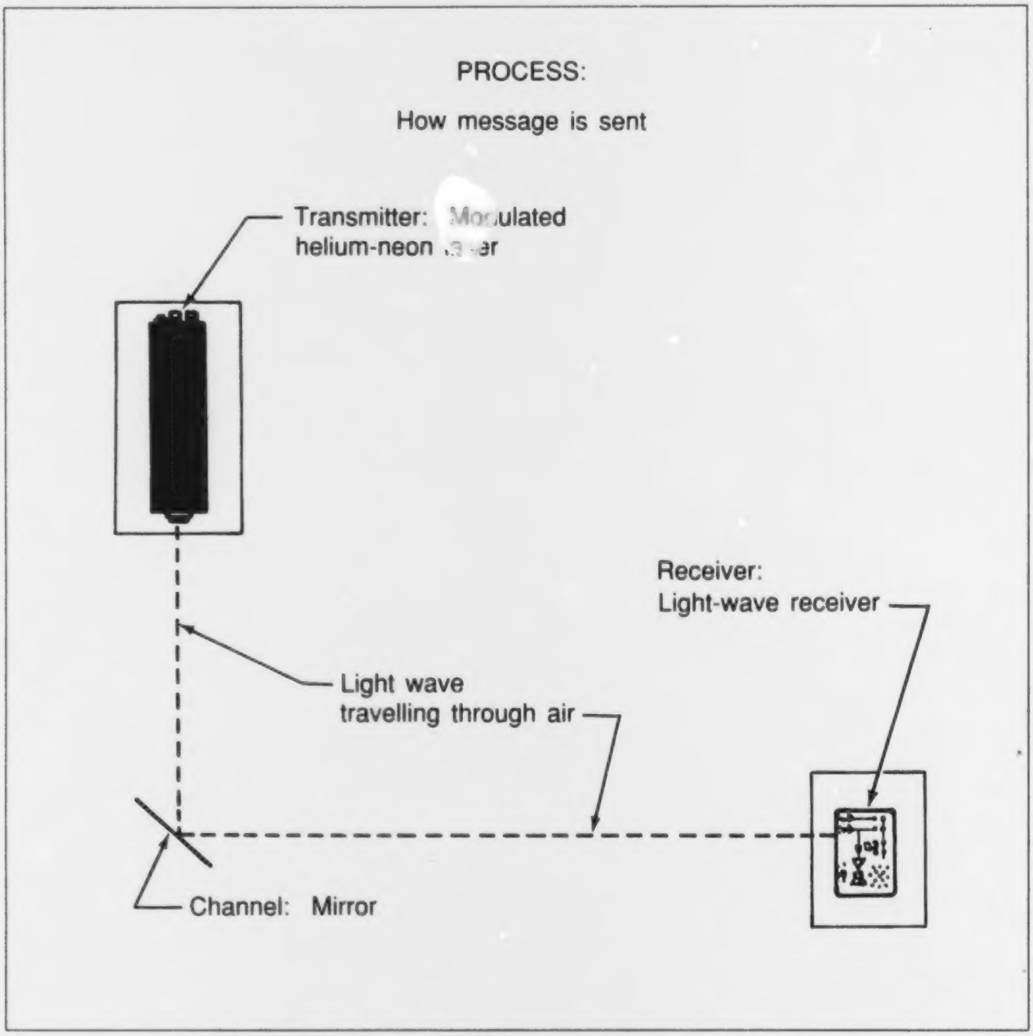
b. **Channel**—Radio beam travelling through atmosphere and retransmitted by satellite

c. **Receiver**—Earth receiving station

INFORMATION SHEET

7. **Parts of the process in a helium-neon laser communication system and their descriptions** (Figure 5)

FIGURE 5


PROCESS:
How message is sent
Transmitter: Modulated helium-neon laser
Receiver: Light-wave receiver
Light wave travelling through air
Channel: Mirror

a. **Transmitter**—Modulated helium-neon laser

b. **Channel**—Light wave travelling through air and reflected by mirror

c. **Receiver**—Light-wave receiver

SATELLITE COMMUNICATION SYSTEMS
UNIT II

STUDENT SUPPLEMENT 1—FINAL DRAFT OF STEP-BY-STEP DUPLICATION PROCEDURE

Directions

Use the following form to record the final draft of the step-by-step duplication procedure you have revised in Assignment Sheet 1. You will transmit this completed procedure as the message in the simulation activity in Lab Activity Sheet 1.

Final draft of duplication procedure

STUDENT SUPPLEMENT 1

SATELLITE COMMUNICATION SYSTEMS
UNIT II

STUDENT SUPPLEMENT 2—MESSAGE RECORD FORM

Directions

Make several copies of the following form to be used by your assistant in Lab Activity Sheet 1, "Use a Laser to Simulate Satellite Communication." Your assistant will use a copy of the following form each time it is necessary to retransmit and re-record the message. Write the number of each attempt on the blank provided.

Attempt number ______________________________

Message recorded ______________________________

STUDENT SUPPLEMENT 2

SATELLITE COMMUNICATION SYSTEMS
UNIT II

STUDENT SUPPLEMENT 3—INTERFERENCE RECORD FORM

Directions

Make several copies of the following form to be used by you in recording source(s) of interference in Lab Activity Sheet 1, "Use a Laser to Simulate Satellite Communication." You will use a copy of the following form each time it is necessary to retransmit and re-record the message. Write the number of each transmission attempt on the blank provided.

Attempt number ______________________________

Source(s) of interference ______________________________

SATELLITE COMMUNICATION SYSTEMS
UNIT II

ASSIGNMENT SHEET 1—PRACTICE CONSTRUCTING AN INTERFERENCE-FREE MESSAGE

Name ______________________________ Score ______________

Introduction

When two people stand face to face in a room and speak to each other, they form a basic communication system including an input, a process, and an output. The input is the message the sender wants to communicate, the process is the words the sender uses to communicate the message, and the output is the message that is actually received by the other person.

Because you function as an element of this type of basic communication system many times every day, you may not be aware of just how difficult it is to eliminate interference from even this basic communication system. Interference can occur during each of the stages in this simple system.

During the input stage, the sender may create a poorly constructed message. By selecting ambiguous words or inaccurate phrases, the sender may construct a message that cannot communicate the idea he or she wishes to send. Therefore, the sender created interference in the first stage of the communication process.

During the process stage—when the sender actually speaks the message and the sound is carried through the air to the other person—many sources of interference are possible. For example, noise in the room may create enough interference that the words of the sender are actually drowned out.

Even if interference does not occur in the process stage, the receiver can experience two forms of interference at the output stage. The person receiving the message may (1) misinterpret even a well-constructed message or (2) be unable to understand a message that was poorly constructed to begin with.

When people stand face to face in the basic communication system described above, they can see each other's facial expressions and ask questions of each other to clarify the sender's message. In doing so, feedback has been added, closing the loop in the communication system and providing the sender with the information he or she needs to know in order to learn how to communicate better.

ASSIGNMENT SHEET 1

Interference problems become even more likely to occur when two people try to communicate over a long distance, when high-tech machines are involved in the process stage of the communication system, and when, because of the distances involved, feedback is harder to obtain. In this type of communication system, it becomes critical to eliminate as much interference as possible from the system before the message is communicated. In other words, the message must be well constructed at the input stage—the message must be constructed to be as interference-free as possible.

In Lab Activity Sheet 1, you will simulate satellite communication. You will attempt to communicate long distance with another person. You will use a laser and a receiver in the process stage of this communication system. In the simulation, as would be the case in an actual satellite communication, you will not be allowed immediate feedback with the person receiving and recording the message you send. Therefore, it will be critical that the message you send be as well constructed and as interference free as possible.

In the exercise in this assignment sheet, you will practice eliminating interference from the input stage of the communication system. You will write a message and then revise it to try to eliminate from it any ambiguous words or inaccurate phrases. Then, you will record this revised message on Student Supplement 1.

Exercise **Write an interference-free message**

Directions Write a checkmark on the blank before each step below as you complete it.

______1. Have your instructor fill in the space on the next page with an illustration you will use to write your step-by-step duplication procedure.

______2. Study the illustration and then on the blanks provided in Section A below, write a message that would explain to another person a step-by-step procedure on how to draw the objects in the illustration.

______3. Attempt to complete a drawing that duplicates the illustration by following the steps you have written. During this process revise your message by eliminating any ambiguous words or inaccurate phrases that might be causing interference in your message. Copy your revised procedure on the blanks provided in Section B below.

ASSIGNMENT SHEET 1

_______4. Show the steps you have written and revised to your instructor and have him or her critique the procedure. Revise your procedure as necessary following your instructor's critique. Copy your revised procedure on the blanks provided in Section C below.

_______5. Copy completed procedure on Student Supplement 1, "Final Draft of Step-by-Step Procedure."

Illustration to be duplicated

ASSIGNMENT SHEET 1

Section A: Rough draft of step-by-step procedure for duplicating the above illustration

ASSIGNMENT SHEET 1

Section B: First revision of step-by-step procedure for duplicating the above illustration

ASSIGNMENT SHEET 1

Section C: Second revision of step-by-step procedure for duplicating the above illustration

SATELLITE COMMUNICATION SYSTEMS
UNIT II

ASSIGNMENT SHEET ANSWERS

Assignment Sheet 1

Evaluated to the satisfaction of the instructor

(EVALUATOR'S NOTE: Writing a step-by-step procedure may be more difficult for the students than it may first appear and may require several rough drafts. Students should be graded on the quality of the improvements made between the first draft of the procedure and the final draft, recorded on Student Supplement 1.)

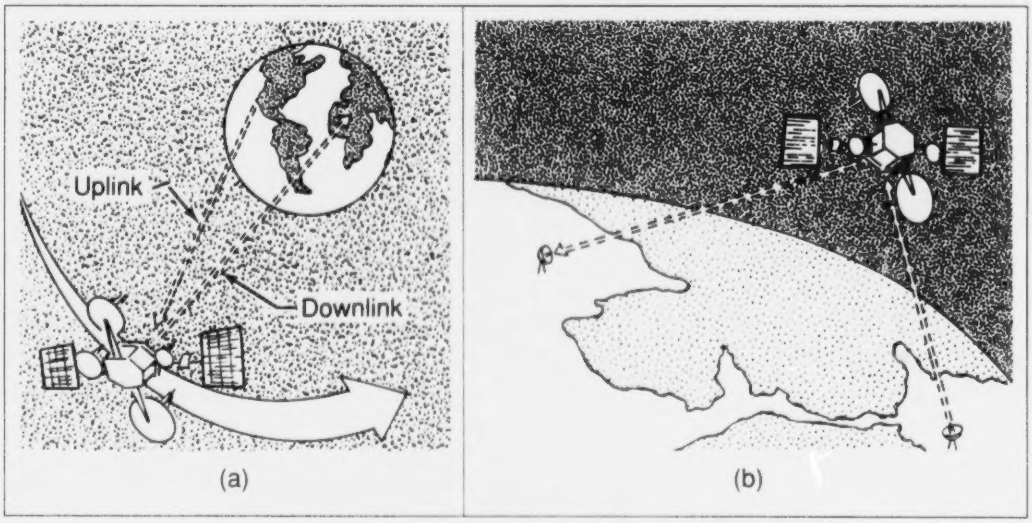
SATELLITE COMMUNICATION SYSTEMS
UNIT II

LAB ACTIVITY SHEET 1—USE A LASER TO SIMULATE SATELLITE COMMUNICATION

Introduction

A communication satellite is really a radio relay station in geostationary (**geo** means *earth* and **stationary** means *fixed*) orbit over the Earth. See Figure 1-a. Radio signals are sent (transmitted) to an orbiting satellite from an earth station, a large, pie-shaped antenna. This upward transmission is called an *uplink*. The satellite receives the signal and retransmits it back to Earth. This downward transmission is called a *downlink*. A receiving earth station captures the signal. See Figure 1-b.

FIGURE 1



(a) (b)

A satellite transmits the signal back to Earth at an angle much the same way that a beam of light can be reflected by a mirror. In this lab activity sheet, you will use the beam of light created by a laser and a mirror to simulate a satellite communication system.

Principle of sound transmission

The same scientific principle applies to sound transmission carried by either radio waves or light waves: ***Messages can be carried as signals on a vibrating band of energy***. Both lasers and radio transmitters produce vibrating bands of energy that can be modified to transmit sound.

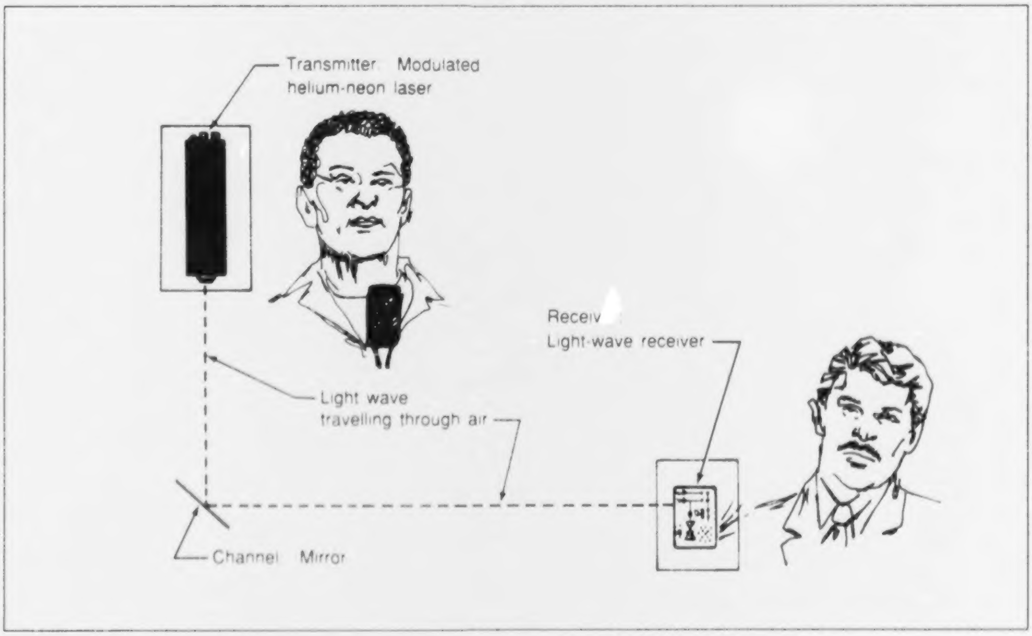
LAB ACTIVITY SHEET 1

When you speak into a microphone, sound waves of various intensity hit the microphone. Electrical circuitry in the microphone produces a varying electrical signal in response to the vibrations in the sound waves hitting the microphone. This varying electrical signal is then amplified (made stronger) and then modulated (superimposed on the wave length of the original energy band produced by the radio or laser), which creates variations in the energy band.

In satellite communication, the amplified electrical signal is modulated with a radio carrier wave and transmitted through the atmosphere, where it is picked up by a satellite and retransmitted at an angle back to a receiver on Earth. The circuitry in the receiver demodulates (separates the carrier wave from the signal) and amplifies the signal before sending it to the speaker, where you hear the transmitted message.

In the laser simulation, the amplified electrical signal is modulated with a carrier wave of light and transmitted through the air to a mirror that reflects the light beam at an angle to a receiver containing a photodiode. The photodiode collects the light beam and circuitry associated with the receiver demodulates and amplifies the signal before sending it to the speaker, where you hear the transmitted message. See Figure 2.

FIGURE 2



LAB ACTIVITY SHEET 1

Laser safety

You will use a helium-neon laser to produce the carrier wave in the simulation activity. As with any other piece of equipment, you should (1) learn the parts of the equipment and (2) learn the safety rules to be followed during use of the equipment.

Your instructor will show you the parts of the laser and receiver used in your laboratory and will demonstrate the proper use. Safety rules to be followed during use of the laser are given below.

Helium-neon lasers emit a low-powered energy beam of red light. This light contains no harmful radiation, and you should not confuse it with the light emitted by the powerful lasers used for burning, cutting, or drilling steel or other metals. However, even though the light beam emitted from this type of laser is relatively low powered, it is intense and concentrated and may cause damage to your eyes should they be exposed to the beam for a period of time. Therefore, you must be careful to follow certain eye-safety rules when using the laser.

1. Do not look directly into the laser beam or stare at its bright reflection, just as you should not stare at the sun or any other very bright light source.
2. If the beam is to travel a long distance, keep it close to the ground or overhead so that it does not cross a walkway at eye level. This measure protects the eyes of a person who might accidentally walk through the light beam.
3. When the laser is powered but is not being used for transmission, block the laser by sliding the open/close clip into the CLOSE position.
4. Always warn others before unblocking the laser (sliding the open/close clip into the OPEN position).

Helium-neon lasers generate high voltages similar to those inside a television receiver, and capacitors within the power supply retain potentially harmful voltages for a period of time even after the power has been turned off. To prevent electrical accidents when using the laser, practice the following electrical-safety rules.

1. Each laser is equipped with a UL-approved power cord and a three-prong grounded plug. Always plug the laser into a grounded outlet.
2. The laser housing is sealed to protect the user and to comply with federal laser-safety legislation. Do **not** open the laser housing for any reason.

ACTIVITY SHEET 1

Troubleshooting laser sound-transmission problems

When you set up the components of the simulation activity correctly, you will be able to transmit sound. However, in the laser communication system—as in any other communication system—interference can occur. If you are unable to transmit sound with the laser, check the following list for possible sources of interference.

1. Is the laser powered (the power cord plugged into a proper outlet)?
2. Is the power switch on the laser turned to the ON position?
3. Is the microphone powered (plugged into the laser microphone jack)?
4. Is the microphone switch turned to the ON position?
5. Is the power switch on the receiver turned to the ON position?
6. Is the laser beam aimed directly into the proper photodiode on the receiver?
7. If using a battery-powered receiver, is the battery dead or low in power?
8. Is the audio switch on the receiver turned to the ON position?
9. Are you speaking softly into the microphone during transmission? If the volume of the sound being fed into the microphone is too strong, excessive modulation will occur, causing the laser to "blink." Speak softly to prevent this type of interference.

Equipment and Materials

- Hard-seal modulated helium-neon laser and manufacturer's instruction manual
- Microphone supplied with laser
- 3-inch focal-length lenses supplied with laser
- Light-wave receiver
- Movable, adjustable stand and strapping mechanism for laser
- Movable stand and strapping mechanism for receiver
- Mirror (flat, silvered glass, 100 mm × 100 mm)
- Ring stand to hold mirror
- Classmate to serve as an assistant
- Copy of Student Supplement 1 with your recorded message

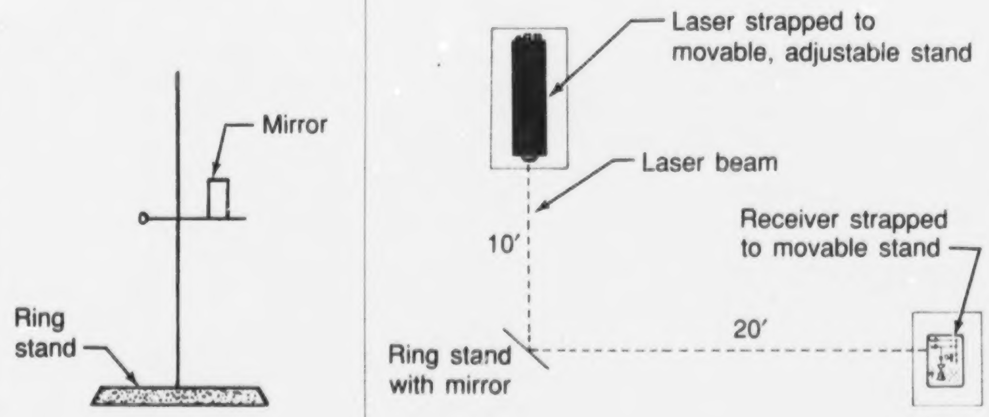
LAB ACTIVITY SHEET 1

- Copy of Student Supplement 2, where your assistant will record transmitted message
- Copy of Student Supplement 3, where you will record the source of any interference occurring during the activity
- Two pencils (one for you and one for your assistant)

Procedure

1. Place laser on movable, adjustable stand and strap laser firmly in place
2. Follow manufacturer's instructions for installing 3-inch focal-length lenses on laser
3. Place receiver on movable stand and strap receiver firmly in place
4. Place laser stand, receiver stand, and mirror on ring stand as shown in the diagram below (see Figure 3)

FIGURE 3


Mirror
Ring stand
Laser strapped to movable, adjustable stand
Laser beam
10′
Receiver strapped to movable stand
20′
Ring stand with mirror

(a) Front view of mirror and ring stand

(b) Top view of setup of all components

5. Check to be sure that laser is blocked (open/close clip is in the CLOSE position); block laser *if* necessary
6. Plug laser power cord into properly grounded power outlet

LAB ACTIVITY SHEET 1

7. Turn laser power switch to ON position

8. Have assistant turn receiver power switch to ON position

9. Level laser

   a. Warn assistant and any others nearby that you are going to unblock laser

   b. Unblock laser (slide open/close clip to OPEN position)

      (CAUTION: Do **not** look directly into the laser beam.)

   c. Following assistant's directions, adjust laser stand height as necessary to align (level) laser beam with photodiode in receiver (see Figure 3-b)

10. When assistant indicates that laser beam is level with receiver photodiode, block laser beam

11. Plug microphone into laser microphone jack and then turn microphone power switch to ON position

12. Instruct assistant to turn receiver power switch and receiver audio switch to ON position

13. Instruct assistant to prepare to receive and record message

14. Warn others that you are going to unblock laser

15. Unblock laser

    (CAUTION: Do **not** look directly into the laser beam.)

16. Read message you recorded on Student Supplement 1, speaking softly into microphone

    (NOTE: If the volume of the sound being fed into the microphone is too strong, excessive modulation will cause the laser to "blink." Speak softly to prevent this type of interference.)

17. Have assistant record message on Student Supplement 2, "Message Record Form"

18. Block laser

19. Retrieve Student Supplement 2 from assistant and compare message you recorded on Student Supplement 1 to message assistant recorded on Student Supplement 2

LAB ACTIVITY SHEET 1

20. *If* assistant was unable to record message successfully, determine source of interference and record interference source on Student Supplement 3, "Interference Record Form"

    (NOTE: If the interference seems to result from noise in the transmission process, determine source by going through the checklist presented in the introduction to this lab activity sheet. If the interference seems to result from the construction of the message sent, determine source by checking for ambiguous words or inaccurate phrases.)

21. Correct source of interference and repeat steps 10 through 20 as necessary until message is successfully transmitted and recorded

22. Have assistant turn receiver audio switch and power switch to OFF position

23. Unplug microphone from laser, turn laser power switch to OFF position, and unplug laser from power outlet

24. Return equipment and materials to proper storage

SATELLITE COMMUNICATION SYSTEMS
UNIT II

WRITTEN TEST

Name ______________________________ Score ______________

1. State the definitions of the terms *communication* and *interference*. Write your answers on the blanks provided below.

   a. Communication ______________________________

   ____

   ____

   ____

   ____

   b. Interference ______________________________

   ____

   ____

   ____

   ____

2. List and define the stages of a basic communication system. Write your answers on the blanks provided below.

   a. **Stage 1** ______________________________

   Definition ______________________________

   ____

   b. **Stage 2** ______________________________

   Definition ______________________________

   ____

   c. **Stage 3** ______________________________

   Definition ______________________________

   ____

WRITTEN TEST

3. Describe forms of interference that can occur at various stages in a basic communication system. Write your answers on the blanks provided below.

   a. **Stage 1** ____

   ____

   b. **Stage 2** ____

   ____

   c. **Stage 3** ____

   ____

4. Discuss the importance of feedback in a basic communication system. Write your answers on the blanks provided below.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

   ____

5. Define the parts of the process in a basic communication system. Write your answers on the blanks below.

   a. Transmitter ____

   ____

   b. Channel ____

   ____

   c. Receiver ____

   ____

WRITTEN TEST

6. Describe the parts of the process in a satellite communication system. Write your answers on the blanks provided below.

   a. Transmitter ____________________

   b. Channel ____________________

   c. Receiver ____________________

7. Describe the parts of the process in a helium-neon laser communication system. Write your answers on the blanks provided below.

   a. Transmitter ____________________

   b. Channel ____________________

   c. Receiver ____________________

SATELLITE COMMUNICATION SYSTEMS
UNIT II

WRITTEN TEST ANSWERS

1. a. Process by which information is exchanged between individuals or machines through a common system of signs, symbols, or behavior
   b. Anything that blocks the communication process

2. a. **Stage 1**—Input
   Definition—Message sender wants to communicate
   b. **Stage 2**—Process
   Definition—How message is sent
   c. **Stage 3**—Output
   Definition—Message actually recorded by person receiving transmission

3. a. **Stage 1**—Sender creates poorly constructed message
   b. **Stage 2**—Noise is created during transmission
   c. **Stage 3**—Person receiving transmission misinterprets message transmitted or receives poorly constructed message

4. Discussion should include the following:

   a. *Feedback* is the term used to describe the contact between person receiving transmission and sender
   b. Feedback closes loop in basic communication system by providing a way of comparing message sent to message recorded after transmission
   c. Feedback tells sender whether person receiving transmission has understood message correctly, and if not, helps sender determine source of interference

5. a. Means of transmitting message
   b. Route message takes
   c. Means of accepting transmitted message

6. a. Earth sending station
   b. Radio beam travelling through atmosphere and retransmitted by satellite
   c. Earth receiving station

7. a. Modulated helium-neon laser
   b. Light wave travelling through air and reflected by mirror
   c. Light-wave receiver

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

UNIT OBJECTIVE

After completing this unit, the student should be able to define *composite materials*, describe processes used in manufacturing composite materials, and fabricate and test model airframe components made from composite materials. The student will demonstrate these competencies by completing the assignment sheet, lab activity sheets, and written test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with airframe manufacturing to their correct definitions.
2. Match components of the manufacturing system model to their correct definitions.
3. Define the term *manufacturing technology*.
4. Describe NASA's role in aeronautics manufacturing technology.
5. Define the term *composite material*.
6. Distinguish between descriptions of the types of bonding processes used in manufacturing composite materials.
7. Match the major types of composite materials used in airframe manufacturing to their correct definitions.
8. Calculate strength-to-weight ratios. (Assignment Sheet 1)
9. Fabricate composite materials. (Lab Activity Sheet 1)
10. Construct and test wing spars. (Lab Activity Sheet 2)

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

SUGGESTED ACTIVITIES

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review teaching suggestions given in the "Delivery and Application" section and plan classroom activities.

  Plan presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain materials to supplement instruction of this unit. See ordering information in the "Suggested Resources" section.
- Obtain competency profiles for this unit. See ordering information in the "Suggested Resources" section.
- Prepare classroom and lab. Put up posters, charts, and signs; display articles related to the objectives of this unit.
- Carefully review Lab Activity Sheets 1 and 2 and prepare all materials required for your students to complete the activities. For Lab Activity Sheet 2, you will need to construct an *attachment point* into which students will insert their wing spars for testing. See the construction diagram for this attachment point in Teacher Supplement 1, "Attachment-Point Construction Diagram." For this same activity sheet you will also need to supply students with solid-wood blocks from which they will cut wing spars. Check Student Supplement 1, "Wing-Spar Pattern" to determine the required dimensions of these blocks.

Delivery and Application

Unit introduction

- Provide students with objective sheet. Discuss unit and specific objectives.
- Provide students with information sheet. Discuss information sheet.

Objective 1 Match terms associated with airframe manufacturing to their correct definitions.

- Explain to students that the two major structural divisions of an airplane are the *airframe* and the *power plant* and that in this unit they will be studying some of the new materials being developed to be used in manufacturing structural components. Use TM 1 to illustrate your explanation.

SUGGESTED ACTIVITIES

Further explain to students that the terms *aramid*, *graphite*, *matrix*, *epoxy resin*, *polyimide resin*, and *bonding* will be used in association with the new materials they will study. Review with students the definitions of these terms and show examples if available.

Objectives 2 through 5

- Review with students the components of a manufacturing system (Objective 2) and discuss how advancements in technology affect the system model (Objective 3). Then discuss NASA's role in advancing manufacturing technology in this country (Objective 4): By Congressional mandate, NASA is charged with stimulating the widest possible use of the technological advances it generates. Through its Technology Utilization Program, NASA seeks to encourage greater use of these technological advances by providing a link between the technology and those who might be able to put it to advantageous secondary use.

  Hand out copies of Teacher Supplement 2, "NASA *Spinoff* Articles," read these articles with the class and use the articles as the basis of a discussion on how NASA has aided the advancement of technology utilization in this country's airframe manufacturing industry through the development of the new composite materials (Objective 5).

Objectives 6 and 7

- Discuss with the class the types of bonding processes used in manufacturing composite materials (Objective 6) and how these different bonding processes are reflected in the differences in the fabrication processes used in creating the two major types of composite materials used in airframe manufacturing (Objective 7).
- Hand out Lab Activity Sheet 1, "Fabricate Composite Materials," and Student Supplement 1, "Wing-Spar Pattern." Read with students the introduction to the activity and discuss its contents. Then discuss with the students the required dimensions of the finished materials they will fabricate (see Student Supplement 1) and demonstrate the procedures for fabricating the balsa, posterboard, and paper laminate composites. Have students complete Lab Activity Sheet 1.
- Hand out Assignment Sheet 1, "Calculate Strength-to-Weight Ratios." Explain to students that in Lab Activity Sheet 2 they will be required to determine the strength-to-weight ratios of the wing spars they will construct with the laminate composites they have fabricated in Lab Activity Sheet 1.

SUGGESTED ACTIVITIES

Read with students the introduction to Assignment Sheet 1 and discuss. Have students perform the calculations in the sample problem included in the introduction and then develop and present other sample problems for them to calculate together in class. Review with students the procedures for converting English measures to metric measures. Display or hand out conversion tables for this purpose. Have students complete Assignment Sheet 1.

- Hand out Lab Activity Sheet 2, "Construct and Test Wing Spars," and Student Supplement 2, "Test-Result Form." Read the introduction to the lab activity and discuss, and then demonstrate the procedure in the lab activity. Discuss also the correct use of Student Supplement 2. Have students complete Lab Activity Sheet 2.

Evaluation

- Give written test.
- Compile written-test and lab-activity-sheet scores.
- Reteach and retest as required.
- Complete appropriate section of competency profiles.

Suggested Resources

Resources used in developing unit

Print media

- Haggerty, James. National Aeronautics and Space Administration, Office of Commercial Programs, Technology Utilization Division. *Spinoff 1985* and *Spinoff 1986*. Washington, D.C.: U.S. Government Printing Office.

Spinoff is an annual NASA publication produced to promote broader and accelerated use of the ever-growing bank of technical knowledge NASA generates. The intent is to spur expanded national benefit by facilitating the technology readily accessible to those who might put it to advantageous use.

The books are well-designed and the artwork exceptional. Although the reading level is rather high for student use, the quality and design of the articles should inspire the student to want to read them—even if they have to work at it a bit.

These books are for sale by the Superintendent of Documents, U.S. Printing Office, Washington, D.C. 20402.

SUGGESTED ACTIVITIES

- Hexcel Products, Inc. *HEXCEL Honeycomb.* Dublin, California: HEXCEL, March, 1973.

  HEXCEL Honeycomb is a promotional booklet explaining the types, properties, uses, and manufacturing processes of the honeycomb materials produced by the HEXCEL company. The artwork used in the booklet is well-done and the booklet would be a good addition to your resources for this unit.

  The mailing address for the administrative offices of the HEXCEL company is 11711 Dublin Boulevard, Dublin, California 94566, or the offices can be reached by calling (415) 828-4200.

- Taylor, John W.R., ed. *The Lore of Flight.* Crescent Books, distributed by Crown Publishers, Inc., New York, copyright 1986.

  The Lore of Flight is an oversized picture book divided into four main sections covering the historical background, the structure of airplanes, engines and equipment, and finally, a chapter on flying today discussing all aspects of a typical transatlantic flight and in contrast, the technicalities involved in flying a small aircraft.

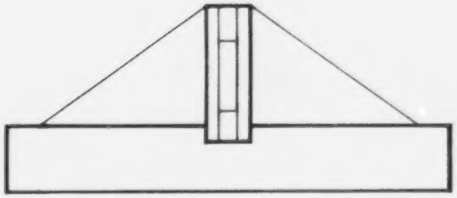
  The book is beautifully illustrated with over 200 color technical drawings and over 150 black and white drawings. The book also contains an index with more than 1550 entries supplementing the main text.

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

TEACHER SUPPLEMENT 1—ATTACHMENT-POINT CONSTRUCTION DIAGRAM

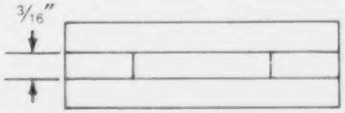
The construction diagram on the following page is of the attachment point students will use in strength-to-weight testing of the wing spars they will construct in Lab Activity Sheet 2. The critical component of this attachment point is the 1-inch-high, ⅜-inch-wide, and 2-inch-deep slot where the spars will be inserted during the testing process. For the tests to be run successfully, the dimensions of this slot must be exact.

The base of the attachment point will be used as a surface for clamping the device to a table or workbench. The size of the base itself is not important as long as the dado groove to be cut in the base is within specified dimensions so that the slot fits snugly into the groove during the testing procedure.

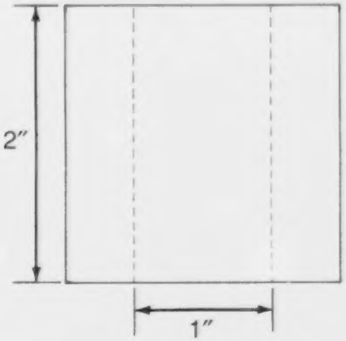


Attachment point should fit very snugly in the dado groove.

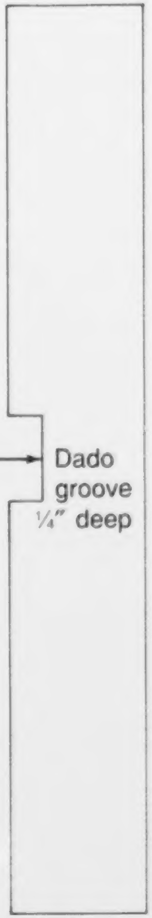
As long as these measurements are correct, the other parts can be any size.



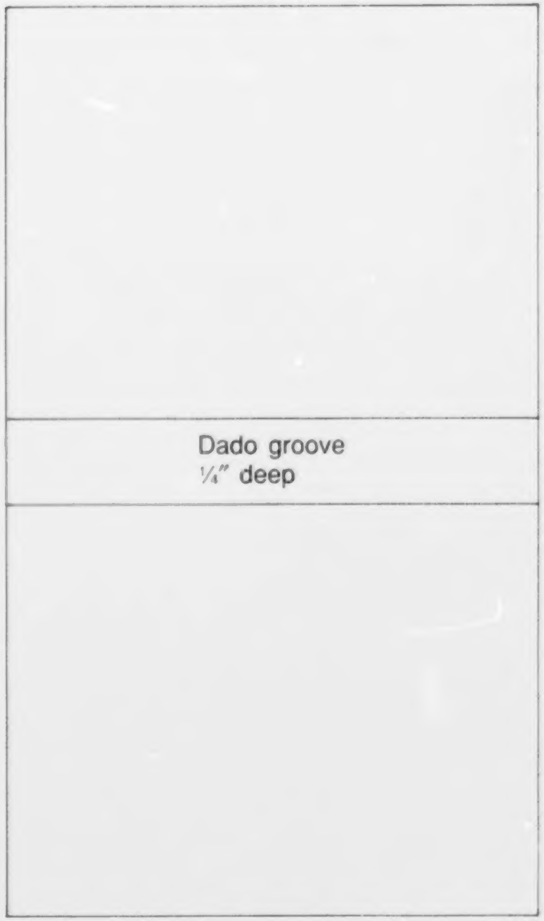
ATTACHMENT POINT (Side view)



ATTACHMENT POINT (End view)


Dado groove ¼″ deep

BASE (Side view)


Dado groove ¼″ deep

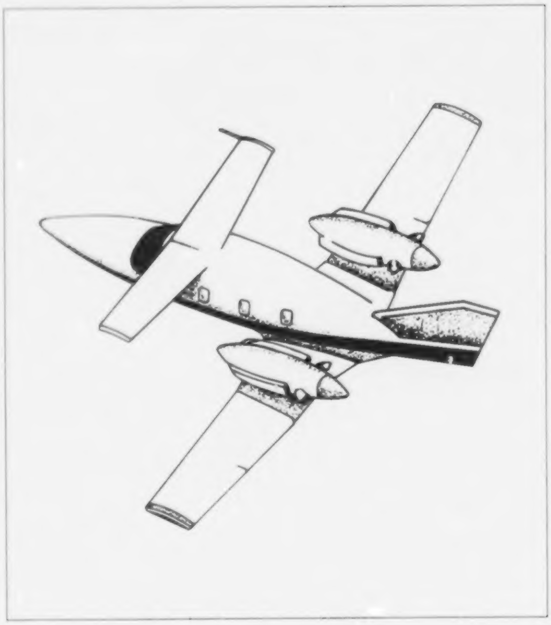
BASE (Top view)

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

TEACHER SUPPLEMENT 2—NASA *SPINOFF* ARTICLES

NASA *Spinoff 1985*, "Composite Materials"

At right is a drawing of the Avtek 400 experimental business airplane, a twin turboprop that has been introduced to flight test. Developed by Avtek Corporation, Camarillo, California, the airplane is distinguished by the fact that its airframe is made entirely of composite materials, which generally are lighter but stronger than the metals they replace. A number of military and commercial aircraft already in operational service have components made of composites, but the Avtek 400 is among the first all-composite aircraft. Increasing use of composites in airframes is a trend of the future because of the singular advantages they offer in comparison with metal structures: improved performance, dramatically lower weight, and in some cases, reduced cost.

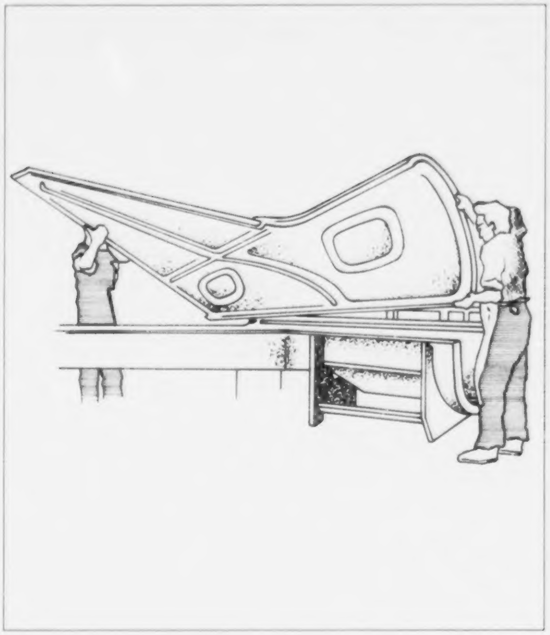


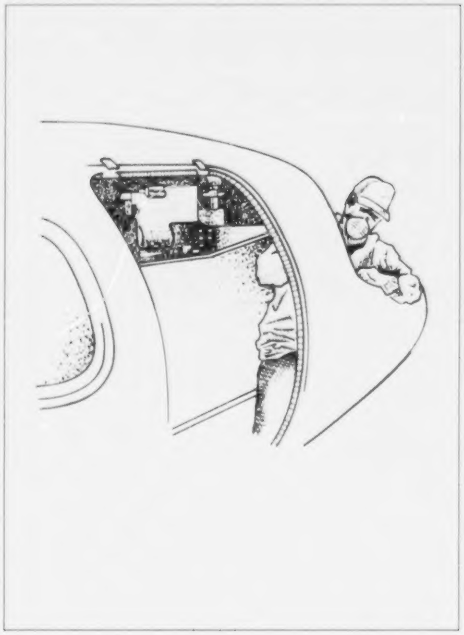
The principle materials used in the Avtek 400 are Kevlar® aramid fiber and Nomex® aramid, both developed by The Du Pont Company, Wilmington, Delaware, a pioneer in the development and manufacture of materials for composites. Kevlar is a fiber that, pound for pound, is five times stronger than steel. Nomex is Du Pont's trade name for a family of high-strength, high-temperature-resistant aramid sheet structures, staple fibers, and filament yarns. More than 70 percent of the Avtek 400 is made of Nomex honeycomb sandwiched between skins of Kevlar fiber. Honeycomb is a series of cells grouped together to form a panel similar in appearance to a cross-sectional slice of beehive honeycomb. It is 90 to 99 percent open space, hence extremely light; when the Nomex core is bonded between two surfaces, the resulting sandwich structure has exceptionally high strength-to-weight and rigidity-to-weight ratios.

Use of Kevlar and Nomex in the Avtek 400 combine to give the airplane a light, tough structure that has a maximum weight of only 5,500 pounds, about half the weight of a metal airplane of comparable size and performance. Composites can be molded into many aerodynamic shapes, eliminating most of the rivets and fasteners required in metal construction. The Avtek 400 is made of 48 molds. The first drawing, next page, shows the aft section and vertical stabilizer; the drawing on the right shows the forward section.

®Kevlar and Nomex are registered trademarks of E. I. Du Pont de Nemours & Company (Inc.).

TEACHER SUPPLEMENT 2





NASA's Langley Research Center in Hampton, Virginia, is among the world's leading facilities involved in research on composite structures. Langley has conducted extensive investigations and tests on applying composites to space vehicles, general aviation and commercial aircraft, and military aircraft and helicopters. Such work included testing Kevlar components that assisted Du Pont in the advancement of its product. Specifically, Langley conducted research in the development of lightweight Kevlar-wound pressure bottles for Space Shuttle use. That development led to the use of similar bottles to activate escape slides in the Boeing 747 and 757 jetliners at a savings of 20 pounds per bottle. A Langley/Lockheed Corporation experimental program involving use of composites—including Kevlar—on the L-1011 transport fostered adoption of fiber-reinforced parts on such new aircraft as the Boeing 757 and 767, both of which employ significant amounts of hybrid structure composed of Kevlar, carbon, and epoxy.

Use of composites is rapidly spreading to their industries, such as boat manufacturing. A large percentage of pleasure and commercial boats already incorporate composites. The trend is being extended to larger vessels to take advantage of the weight reduction and performance gains composites offer.

Du Pont composites are also finding increased use in such applications as transportable military shelters, components of automotive vehicles, protective apparel for people in hazardous professions, ropes and cables for marine use, and a broad variety of industrial uses.

TEACHER SUPPLEMENT 2

NASA *Spinoff 1986*, "Composites for Lighter Structures"

In the never-ending quest for reduced weight in all types of aerospace vehicles, designers are more and more turning their attention toward composite fiber-reinforced materials—fibers bound together in a matrix. The resultant composite is generally lighter yet stronger than the metal it supplants. Extensive research and development over the past two decades resulted in expanding use of composite components, initially in military aircraft and missiles, later in commercial jetliners, more recently in private airplanes. Polymer-matrix composites are also used in a broad range of nonaerospace applications where lower weight is advantageous, such as automobiles, boats, rapid-transit vehicles, and a variety of sports equipment from golf clubs to racing cars.

Until now composites have been limited to uses wherein they encounter only low or moderate temperatures. Composite-materials development took a giant step forward with the first use of a high-temperature polymer-matrix composite component as a primary structural member in a production-type jet engine—General Electric Company's F404, power plant for the Navy's F/A-18 strike fighter. The composite segment is the engine's outer duct, a passageway for "bypass" air, cool air that bypasses the compressor section and is ducted toward the rear of the engine to mix with the hot exhaust gas. The mix increases engine thrust and the cooler bypass air serves as a coolant for afterburner parts that operate at very high temperatures.

The composite material replaces titanium that had to be machined to shape, then chemically milled. Its use in the outer duct trims engine weight, thus contributing to lower fuel consumption, and reduces engine cost by more than $9,000 per unit. Since the F/A-18 is scheduled for high-volume production over several years, savings on that single program may run as high as $30 million—and General Electric is extending the technology to several other engine programs.

The material used in the duct is a fabric woven of Union Carbide's Thornel™ graphite fiber impregnated with a high-temperature polyimide resin. Known as PMR-15, the resin was developed by Dr. Tito T. Serafini and other investigators at NASA's Lewis Research Center in response to a need for a resin capable of withstanding higher temperatures to enable a significant expansion of composite applications. Epoxy resins, the resins most widely used as composite-matrix materials, have excellent mechanical properties and can be processed easily, but they are limited to applications where temperatures do not exceed 350 degrees Fahrenheit. Polymers with theoretically double the temperature resistance posed extraordinary processing difficulties. More than a decade ago the Lewis team started research toward a high-temperature polyimide resin that could be readily processed. After lengthy experimentation involving alteration of the chemical nature of the resin and methods of processing it, they successfully developed PMR-15, which offers good processing characteristics and remains stable at high temperatures, thus allowing fabrication of defect-free fiber-reinforced composites that can operate in an environment of 600 degrees Fahrenheit or more.

But laboratory development of the polyimide was only a milestone; it then had to be converted to a manufacturing material for cost-effective production-line use. In 1979, when

---

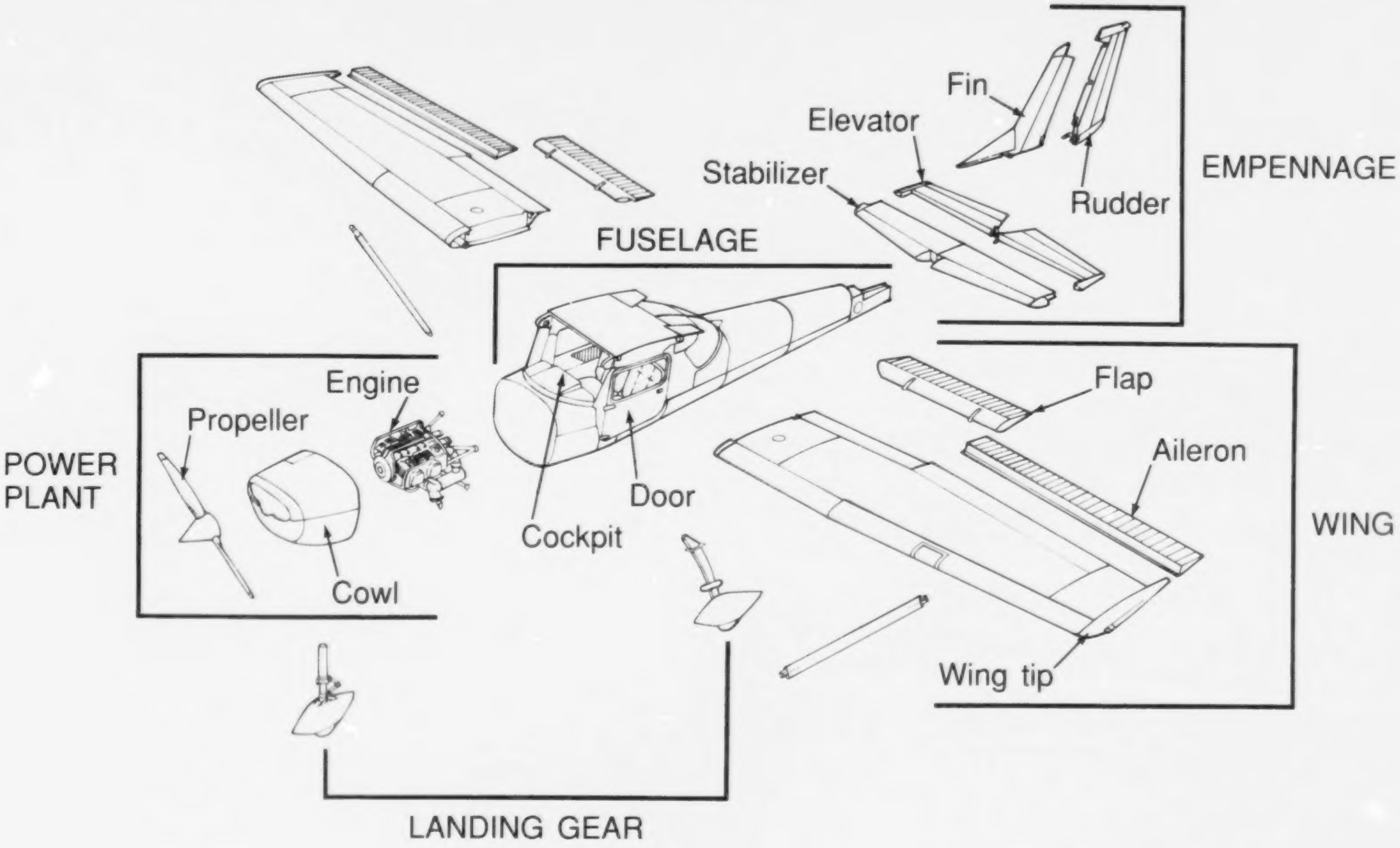
™Thornel is a trademark of Union Carbide.

TEACHER SUPPLEMENT 2

the Lewis-Center work was in an advanced stage and PMR-15 began to look highly promising, General Electric's Aircraft Engine Business Group, looking for a lightweight, low-cost substitute for titanium plate in the F404 engine duct, became interested. There ensued a four-year processing-technology effort, jointly funded by NASA and the Navy, followed by a Navy-sponsored manufacturing-technology program that resulted in a manufacturing process for use of the graphite polyimide composite. Initially clothlike in appearance, the material is cut, layered, and shaped to a desired configuration, then cured in an autoclave, where the fibers and resin are molded under pressure into a component that looks metallic but weighs about 15 percent less than the predecessor titanium duct. Fabricated by General Electric's Albuquerque, New Mexico facility, the F404 composite duct was extensively ground- and flight-tested in 1984-85 and qualified for production-line use beginning in 1986.

The PMR formulation was made available to commercial suppliers of composite materials and General Electric selected Ferro Corporation, Culver City, California, to provide the "prepreg," or resin-impregnated fiber material, for the F404 duct. Other manufacturers are producing composite fabrics and tapes based on PMR-15 for a range of applications that is growing rapidly.

Major Structural Divisions of an Airplane


Fin
Elevator
Stabilizer
Rudder
EMPENNAGE
FUSELAGE
Engine
Propeller
POWER PLANT
Cowl
Cockpit
Door
Flap
Aileron
WING
Wing tip
LANDING GEAR

236

237

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

INFORMATION SHEET

1. **Terms and definitions associated with airframe manufacturing**

   a. **System**—Group of people, procedures, equipment, and resources that function together to produce desired results

   b. **Durable goods**—Products that usually last at least three years

   EXAMPLES: Furniture, refrigerators, automobiles, bicycles

   c. **Nondurable goods**—Products that usually last fewer than three years

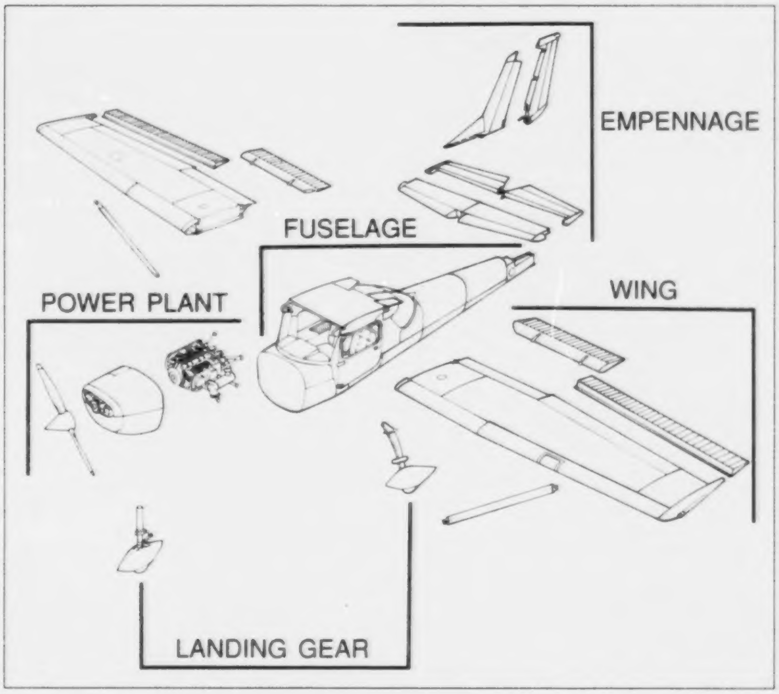
   EXAMPLES: Clothing, food, toothpaste

   d. **Natural resources**—Items taken from the earth, sea, and air

   EXAMPLES: Petroleum, iron ore, cotton, wood, fruits and vegetables, natural gas, oxygen

   e. **Airframe**—Structure of an aircraft without the power plant (Figure 1)

FIGURE 1



INFORMATION SHEET

f. **Power plant**—Engine and related parts that supply the power needed for forward motion in a self-propelled aircraft (see Figure 1)

g. **Aramid**—Any of a group of synthetic materials fashioned into fibers, filaments, or sheets and used especially in textiles and plastics

h. **Graphite**—Soft, black, lustrous carbon

(NOTE: Graphite is the material used in lead pencils.)

i. **Matrix**—Material in which something is enclosed or embedded

j. **Epoxy resin**—Flexible, usually heatset, resin used chiefly in coatings and adhesives

k. **Polyimide resin**—Strong plastic resin developed to withstand extremely high temperatures

l. **Bonding**—Permanent assembly method in which two or more materials are combined using pressure, heat, or glue or some other bonding agent

2. **Components of the manufacturing system model and their definitions**

(NOTE: The components of a manufacturing system can be classified according to the universal system model illustrated in Figure 2 below.)

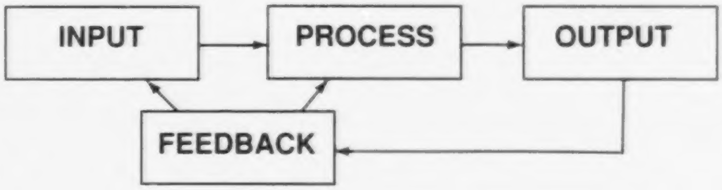
a. **Inputs**—Natural resources, finance, capital, government standards, energy, human resources, and knowledge

b. **Processes**—Management practices, production processes, and personnel practices

c. **Outputs**—Durable and nondurable goods or products

d. **Feedback**—Customer response, profit and loss, and quality control

FIGURE 2



Universal system model

INFORMATION SHEET

3. **Definition of the term *manufacturing technology***—Development of more efficient processes and materials to produce better manufactured products

4. **NASA's role in aeronautics manufacturing technology**—To develop the technology needed to assure safer, more efficient, economical, and environmentally acceptable air-transportation systems

5. **Definition of the term *composite material***—Product produced by bonding two or more materials to form a new and better material for a specific application

6. **Types of bonding processes used in manufacturing composite materials and their descriptions**

   a. **Cohesive bonding**—Process of permanently fusing two or more like materials by melting or softening the materials through the use of heat, pressure, or a solvent

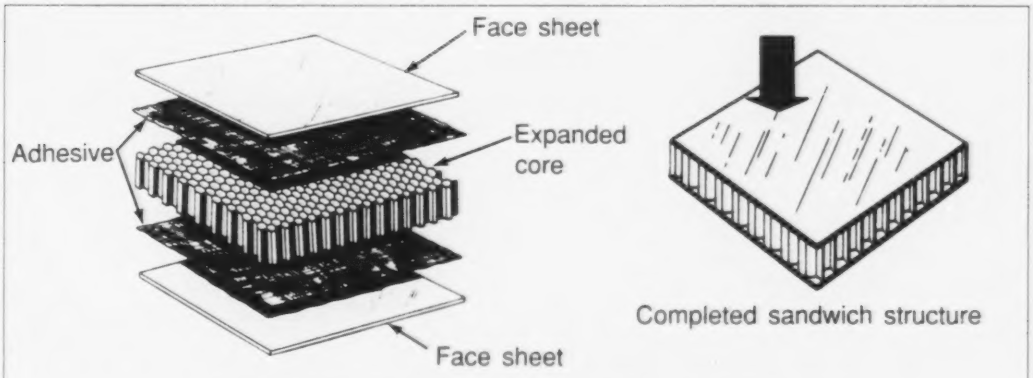
   b. **Adhesive bonding**—Process of using glue or cement to adhere the surfaces of two or more like or unlike materials

7. **Major types of composite materials used in airframe manufacturing and their definitions**

   a. **Aluminum-honeycomb laminate composites**—Layers of materials that are adhesive-bonded to form sandwich-type panels

   (NOTE: Since World War II, aluminum-honeycomb laminate composites have been the most commonly used materials in manufacturing airframe components. Three layers of materials make up a typical aluminum-honeycomb laminate composite "sandwich": [1] face sheets that provide a smooth, rigid surface, [2] adhesive, and [3] an aluminum-honeycomb core. See Figure 3.)

FIGURE 3



Three elements make up a honeycomb sandwich panel: face sheets, core, and adhesive.

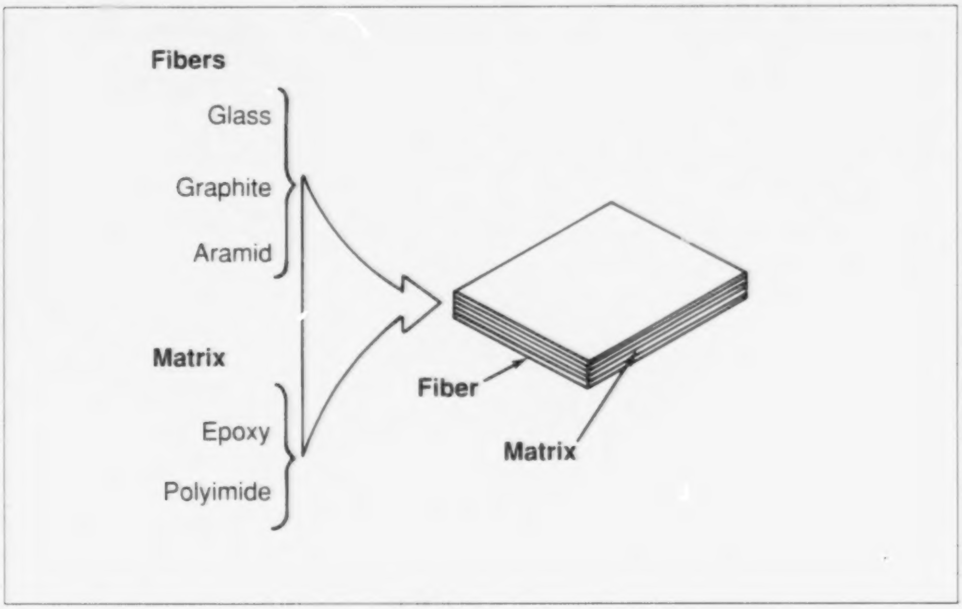
Adapted with permission of Hexcel Products, Inc., Dublin, California, from *HEXCEL Honeycomb*, March, 1973.

INFORMATION SHEET

b. **Advanced fiber composites**—Complex materials in which graphite, glass, or aramid fibers are arranged in a matrix—generally epoxy or polyimide resin—and then heated under pressure to form a cohesively bonded substance that is strong but light and has a great resistance to corrosion and fatigue

(NOTE: In response to the energy crisis in 1973, NASA has worked to develop advanced fiber composite materials to replace metal airframe components with these lighter, stronger, more economical materials. See Figure 4.)

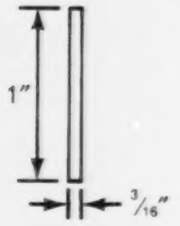
FIGURE 4



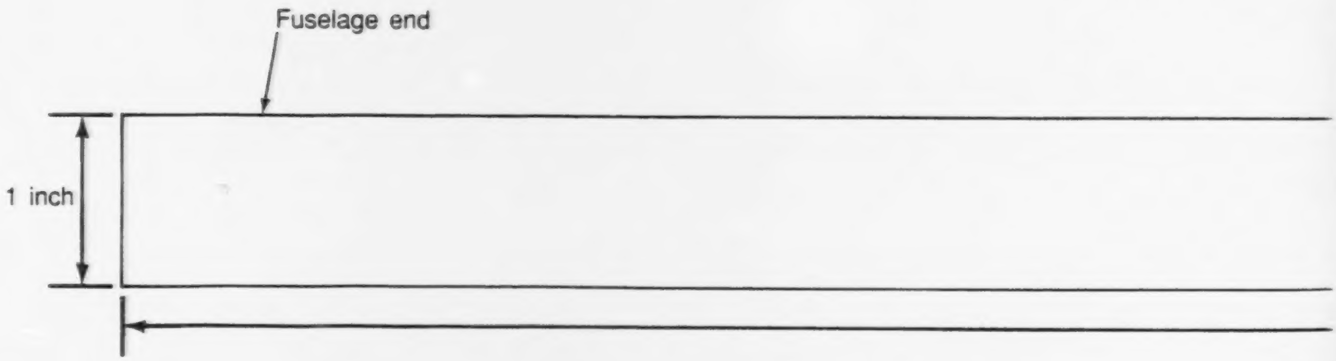
Adapted with permission of the National Aeronautic and Space Administration from *Improved Aircraft Performance Using Composites* by R. J. Pegg, Langley Research Center, n.d.

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

STUDENT SUPPLEMENT 1—WING-SPAR PATTERN

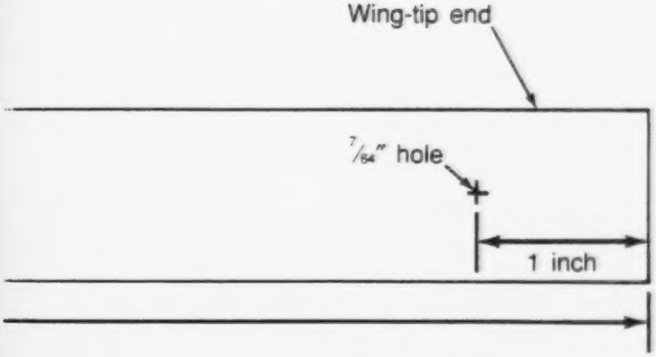


END VIEW


Fuselage end
1 inch

SIDE VIEW

18 inches


Wing-tip end
$^7/_{64}$" hole
1 inch

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

STUDENT SUPPLEMENT 2—TEST-RESULT FORM

Directions Make at least four copies of this form to be used in recording the results of the four tests you will complete in Lab Activity Sheet 2.

Name ______________________________

1. Wing-spar material being tested ______________________________

2. Combined weight of hook, line, and weight hanger ______________________________

   Weight of wing spar ______________________________

3. Beginning wing-spar angle ______________________________

4. In the space below, calculate the combined weight of the weights added to the hanger. Record your answer on the blank provided.

   Combined weight of added weights ____________

5. In the space below, calculate the strength-to-weight ratio of the spar tested. Record your answer on the blank provided.

   Strength-to-weight ratio of spar ____________

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

ASSIGNMENT SHEET 1—CALCULATE STRENGTH-TO-WEIGHT RATIOS

Name ______________________________ Score ______________

Introduction

In Lab Activity Sheet 2 you will build several structural components of a wing called *wing spars*, and you will weigh each spar and test its strength by attaching a weight hanger to the spar and adding weights to the hanger until fails. The weight of the hanger plus the combined weight of the weights added to the hanger determine the load that the spar can handle, or the spar's **strength**. Once the spar's strength is known, you can calculate the strength-to-weight ratio of the wing spar by dividing the strength of the spar by the weight of the spar, or

$$\text{Strength of Spar} = \text{Weight of Hanger} + \text{Added Weight}$$

$$\text{Strength-to-Weight Ratio} = \frac{\text{Strength of Spar}}{\text{Weight of Spar}}$$

For example, if you determine that the weight of a wing spar is 150 pounds, the weight of the hanger is 150 pounds, and the combined weight of the added weights is 1000 pounds, you would calculate the strength-to-weight ratio of the spar as follows.

$$\text{Strength of Spar} = 150\ \text{lb} + 1000\ \text{lb} = 1150\ \text{lb}$$

$$\text{Strength-to-Weight Ratio} = \frac{1150\ \text{lb}}{150\ \text{lb}} = 7.67$$

Airframe designers use strength-to-weight ratios to determine the best materials to be used in their airframe designs—the materials that are strong yet light. The purpose of this assignment sheet is to give you practice in making the strength-to-weight-ratio calculations you must use in Lab Activity 2 to determine which of the wing-spar materials you have used is the strongest yet lightest.

ASSIGNMENT SHEET 1

Exercise

Directions Read each of the following problems and calculate the strength-to-weight ratios of each wing spar. Show your work in the spaces provided and write your answers on the blanks provided.

1. If the hanger weighs 40 pounds, the added weights weigh 760 pounds, and the wing spar weighs 70 pounds, what is the strength-to-weight ratio of the spar?

   Strength-to-weight ratio ____________

2. If the hanger weighs 100 pounds, the added weights weigh 1500 pounds, and the wing spar weighs 100 pounds, what is the strength-to-weight ratio of the spar?

   Strength-to-weight ratio ____________

3. If the strength of a wing spar is .8 tons and the weight of the spar is 85 pounds, what is the strength-to-weight ratio of the spar?

   Hint: Remember to use the same units of weight in making your calculations. In this case, convert your answer to pounds.

   Strength-to-weight ratio ____________

ASSIGNMENT SHEET 1

4. If the hanger weighs 20 pounds, the added weights weigh 460 pounds, and the wing spar weighs 22 pounds, what is the strength-to-weight ratio of the spar?

   Strength-to-weight ratio ____________

5. If the strength of the spar is .5 ton and the weight of the spar is 79 pounds, what is the strength-to-weight ratio of the wing spar?

   Strength-to-weight ratio ____________

6. If the hanger weighs 50 pounds, the added weights weigh 1180 pounds, and the wing spar weighs 57 pounds, what is the strength-to-weight ratio of the spar?

   Strength-to-weight ratio ____________

7. If the hanger weighs 158 pounds, the added weights weigh 1000 pounds, and the wing spar weighs 87 pounds, what is the strength-to-weight ratio of the spar?

   Strength-to-weight ratio ____________

ASSIGNMENT SHEET 1

8. If the strength of the spar is .7 metric ton and the weight of the spar is .025 metric ton, what is the strength-to-weight ratio of the wing spar?

   Strength-to-weight ratio ____________

9. If the strength of a spar is .54 metric ton and the weight of the spar is .027 metric ton, what is the strength-to-weight ratio of the wing spar?

   Strength-to-weight ratio ____________

10. If the strength of a spar is .63 metric ton and the weight of the spar is .04 metric ton, what is the strength-to-weight ratio of the wing spar?

    Strength-to-weight ratio ____________

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

ASSIGNMENT SHEET ANSWERS

Assignment Sheet 1	1.	11.43
	2.	16.00
	3.	18.82
	4.	21.82
	5.	12.66
	6.	21.58
	7.	13.31
	8.	28
	9.	20
	10.	15.75

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

LAB ACTIVITY SHEET 1—FABRICATE COMPOSITE MATERIALS

Introduction

Traditionally, the development of improvements in airframe design has been more of a gradual evolution than the result of a few important breakthroughs in design concepts or materials used in airframe components. One reason for this gradual evolution is that airframe designers have selected airframe materials for very practical reasons, and they have been hesitant to deviate from the use of these materials once selected.

The earliest airframes were wood-and-fabric structures. Designers selected wood as the material of choice for these early airframe designs because workers who would manufacture the structures were familiar with wood and its characteristics and because wood was plentiful, strong, and light enough to suit their designs, even though it was flammable and susceptible to rot.

Designers were content to stay with wood airframes until World War I and II, when airplanes began to be used in combat and the flammability and short service life of wood airframes became a problem. When designers were forced to look for other materials to use for airframe components, aluminum alloys became their material of choice, and in selecting aluminum alloys, designers were again very practical. The technology for manufacturing aluminum alloy had been developed so that the material was relatively cheap. Also aluminum was light for its strength and nonflammable—even though heavier than wood and subject to corrosion and fatigue that limited its service life.

From Word War II until 1973, designers continued to rely on solid aluminum or metal laminate composites fabricated from aluminum honeycomb. However, with the energy crisis of 1973, considerations of total energy consumption, both in manufacturing an aircraft and in its operation and maintenance, prompted designers to look for a lighter, more corrosion- and fatigue-free material to be used in their airframe designs.

In response to a request of the U.S. Senate in 1975, NASA established the Aircraft Energy Efficiency (ACEE) program to develop fuel-saving technologies for both existing and future aircraft. The ACEE, in turn, developed the following major technology programs to explore ways to improve both power-plant and airframe performance:

- More efficient wings and propellers.
- New advanced composite materials for airframes that are lighter and more economical than metal.
- Ways to make today's jet engine more fuel efficient.
- New engine technologies for energy-saving aircraft of the future.

LAB ACTIVITY SHEET 1

In the area of advanced composite materials for airframes, the ACEE, working with Boeing, McDonnell-Douglas, and Lockheed on cost-shared contracts, developed fiber composites and evaluated these new materials in terms of performance and manufacturing costs. These evaluations led the ACEE to conclude that advanced fiber composites could replace metals in airframe designs because of their improved ability to sustain combat damage; greater resistance to corrosion and fatigue, which extends their service life and decreases total costs; and their improved strength-to-weight ratios, which results in fuel-cost savings.

What are advanced fiber composite materials?

Advanced fiber composites are complex materials in which two or more fibers are arranged in a matrix (generally epoxy or polyimide resin) and then heated under pressure to form a strong but light substance with great resistance to corrosion and fatigue.

The fibers most often used in these advanced composite materials are aramid, glass, and graphite. These materials arrive at the fabricator in various forms, including unidirectional fiber or board goods, tape, and woven cloth. Then fabrication of the composite structures takes several forms. Tubular structures, large cylindrical tanks, and the like are made by winding fibers onto a mold while applying the resin matrix. Sheet-like structures are made by laying-up layers of the fibers in molds. Curved structures are molded, and smaller structures like ribs and brackets are stamped or molded. But however the structure is fabricated, the resin-fiber mass finally is heated under pressure to cure it, and if fabricated and cured properly, an extremely strong lightweight material results.

Although aluminum-honeycomb laminate composites still continue to be used in most airframe designs today, designers are beginning to use the new advanced fiber composite materials more and more, and it is predicted that advanced fiber composites will eventually become their material of choice.

Fabricating composite materials

The purpose of this and the next lab activity sheet is to demonstrate the greater strength-to-weight ratios possible when comparing components manufactured from solid materials to components manufactured from composite materials.

In this lab activity, you will fabricate three composite materials, and in the next lab activity, you will construct and test wing components made both from solid wood and from the composite materials you fabricate. Although you will not be using the exotic composite materials discussed above—you will be using balsa, posterboard, and paper sheets to create laminate composites—the strength-to-weight design characteristics associated with composites can be demonstrated with these common materials.

LAB ACTIVITY SHEET 1

Equipment and Materials

- Student Supplement 1, "Wing-Spar Pattern"
- Desk or other flat work surface
- Newspaper or other large sheets of scrap paper
- Boards and C-clamps
- Balsa-wood sheet material
- Posterboard strips
- Paper strips
- Glues (white glue and wood glue)
- Pencil
- Ruler
- Scissors

Procedure

1. Study the wing-spar pattern in Student Supplement 1 to determine specified dimensions for wing spar

2. Determine required dimensions of fabricated laminate needed to meet specific dimensions of wing spar

   (NOTE: Be sure to allow enough area on the finished fabricated materials so that the wing-spar pattern in Student Supplement 1 can be easily transferred onto the fabricated laminate composite.)

3. Spread scrap paper over work surface to protect it from glue

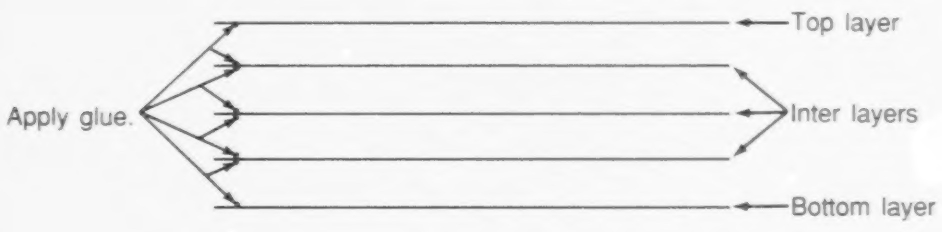
4. Fabricate balsa laminate composite

   a. Estimate and select quantities of balsa needed to meet dimensions determined in step 2

   b. Study the gluing pattern in Figure 1 below

      (NOTE: Gluing the layers together in the following pattern—with glue on both sides of most of the sheet material—will make the laminate composite stronger.)

FIGURE 1



Gluing pattern

LAB ACTIVITY SHEET 1

   c. Following gluing pattern, spread wood glue evenly over the surfaces of the balsa sheets, bonding layers until materials meet required dimensions determined in step 2

   d. Place balsa laminate composite between two boards and secure with C-clamps to prevent warping; allow composite to dry

5. Fabricate posterboard laminate composite

   a. Estimate and select quantities of posterboard needed to meet dimensions determined in step 2

   b. Following the gluing pattern in Figure 1 above, spread white glue evenly over the surfaces of the posterboard strips, forming layers until materials meet required dimensions determined in step 2

   c. Place posterboard laminate composite between two boards and secure with C-clamps to prevent warping; allow composite to dry

6. Fabricate paper laminate composite

   a. Estimate and select quantities of paper needed to meet dimensions determined in step 2

   b. Thin white glue to a watery consistency

   c. Following the gluing pattern in Figure 1 above, use paint brush to spread white glue evenly over the surfaces of the paper strips, forming layers until layered materials meet required dimensions determined in step 2

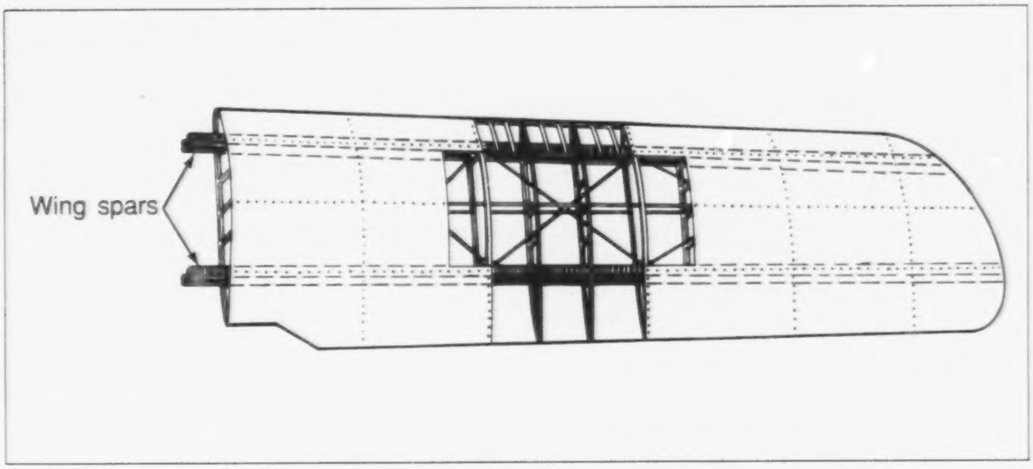
   d. Place paper laminate composite between two boards and secure with C-clamps to prevent warping; allow composite to dry

   (NOTE: The paper laminate composite material will take longer to dry than the balsa or posterboard material.)

7. Clean work surface and return equipment and materials to proper storage

LAB ACTIVITY SHEET 2

FIGURE 2



In this activity sheet, you will construct four small-scale wing spars—three spars made from the composite materials you fabricated in Lab Activity Sheet 1 and one from solid wood. Then you will test the strength-to-weight ratios of these four wing spars by placing each spar into a device called an *attachment point* and adding weights to the end of the spar until the spar fails. Next, you will use the skills you learned in Assignment Sheet 1 to calculate the strength-to-weight ratio of each wing spar and determine which of the materials used is the strongest yet lightest.

Equipment and Materials

- Balsa, posterboard, and paper laminate composite materials fabricated in Lab Activity Sheet 1
- Piece of solid wood provided by instructor
- Student Supplement 1, "Wing-Spar Pattern"
- Pencil
- Ruler
- Carbon paper
- Posterboard
- Narrow-bladed handsaw such as a coping saw or keyhole saw
- Scissors
- X-acto knife
- Eye protection
- Sandpaper
- File
- Attachment point provided by instructor
- Table or workbench
- C-clamp
- Protractor

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

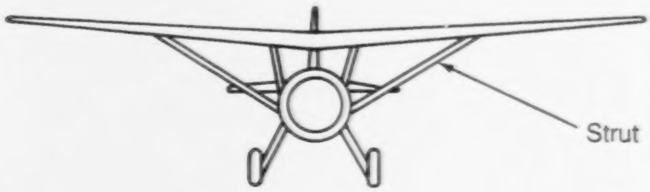
LAB ACTIVITY SHEET 2—CONSTRUCT AND TEST WING SPARS

Introduction

Airframe designers are faced with three major problems in creating aircraft wing designs. When an airplane moves through the air during flight, the wings become the major load-bearing members of the airframe. Therefore, the designer must develop extremely strong wings to withstand the loads. Although wings must be strong, the designer must also make them light enough to minimize the downward force of gravity (weight), and their overall design clean-lined enough to reduce the backward force (drag) as the craft moves through the air. Three criteria an airframe designer must keep in mind, then, are strength, clean lines, and light weight.

Early airframe designers used fabric-covered wood for wing structural components because of wood's light weight. However, these light, fabric-covered wood structures proved not to be strong enough, so designers added external braces called *wing struts* to strengthen the wing structure. See Figure 1. While strengthening the wing structure, struts interfered with the clean lines of the design and created drag.

FIGURE 1



Externally braced wings

To create a more clean-lined design, designers eventually developed an internally supported wing structure called a *cantilever wing*. *Cantilever* is an engineering term for a projecting beam that is rigidly fixed at one end. A cantilever wing is a wing design that contains one or two projecting beams that have one end fixed at the fuselage and the outer end free to move up and down to accommodate variations in the loads placed on the wing. See Figure 2. The projecting beams used in a cantilever wing are called *wing spars*.

LAB ACTIVITY SHEET 2

- Two-foot length of 20- to 30-pound test fishing line
- Drill and drill bit
- Four copies of Student Supplement 2, "Test-Result Form"
- Scale
- Weight hanger and weights
- Ceiling hooks and pulleys

Procedure

1. Create posterboard wing-spar pattern
    a. Locate the wing-spar pattern in Student Supplement 1
    b. Using pencil, ruler, and carbon paper, transfer spar pattern onto posterboard

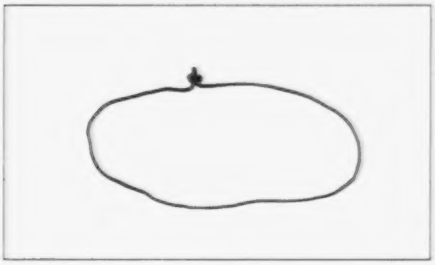
       (NOTE: It is important that the transfer pattern be as accurate as possible.)
    c. Using scissors, rough-cut around posterboard pattern piece
    d. Using X-acto knife, trim posterboard, pattern piece to exact dimensions
2. Transfer wing-spar pattern onto solid-wood and laminate composite materials
    a. Place posterboard pattern on top surface of each material and secure in place
    b. Using a pencil, carefully trace around posterboard pattern
3. Form wing spars from solid-wood and laminate composite materials
    a. Rough-cut around pencil marks, using scissors and X-acto knife for posterboard and paper laminate composite materials and narrow-bladed saw for balsa laminate composite and solid-wood materials
    b. File and/or sand materials to remove excess material and shape wing spars to exact dimensions
4. Prepare each wing spar for testing
    a. Consult wing-spar pattern to determine proper placement for $\frac{7}{64}$-inch hole; mark hole location on wing spar
    b. Drill $\frac{7}{64}$-inch hole on wing spar

LAB ACTIVITY SHEET 2

c. Attach fishing line to hole on wing spar

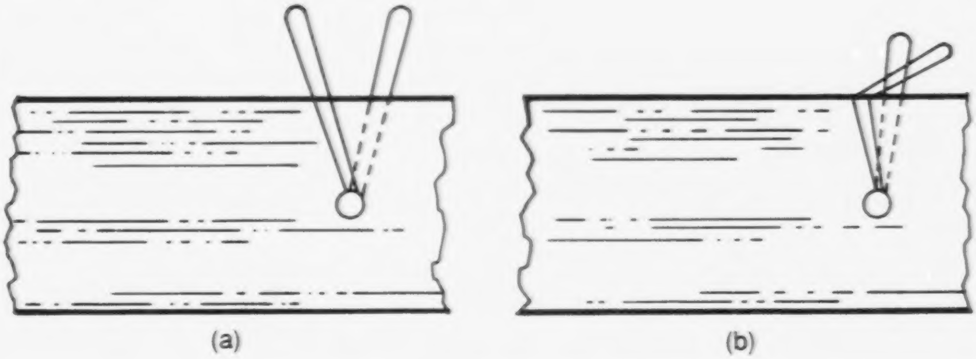
- Tie ends of fishing line together to form a loop as shown in Figure 3 below

FIGURE 3



- Slide loop through hole on wing spar and then slip one end of the loop through the other as shown in Figure 4

FIGURE 4



(a) (b)

5. Construct pulley system

   a. Study diagram in Figure 5 below

   b. Clamp attachment point to table or workbench as shown in Figure 5

   c. Attach hooks and pulleys to ceiling as shown in Figure 5

LAB ACTIVITY SHEET 2

d. Determine amount of fishing line needed for pulley system

(NOTE: The amount of fishing line required will vary depending on the height of the ceiling in the lab, the height of the table or workbench, and the distance between the pulleys.)

e. Weigh fishing line, hook to be placed at end of fishing line (see Figure 5), and weight hanger; record on Student Supplement 2

f. String fishing line through pulley system

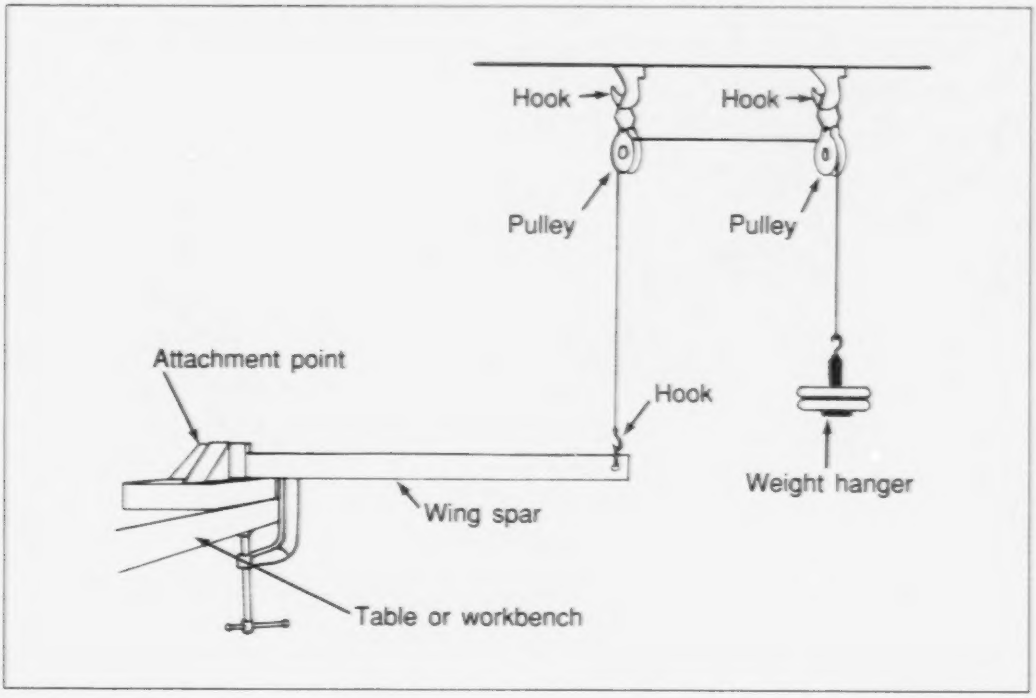
g. Make a loop at each end of fishing line

h. Attach hook to loop at end of fishing line over table or workbench; see Figure 5

(NOTE: This hook will be attached to the wing-spar loop that was constructed in step 4. See Figure 5.)

i. Attach weight hanger to loop at other end of fishing line; see Figure 5

FIGURE 5


Hook
Hook
Pulley
Pulley
Attachment point
Hook
Weight hanger
Wing spar
Table or workbench

LAB ACTIVITY SHEET 2

6. Test wing spar
    a. Record on Student Supplement 2 wing-spar material type being tested
    b. Weigh wing spar and record spar weight on Student Supplement 2
    c. Insert fuselage end of wing spar into attachment point; see Figure 5
    d. Attach hook on pulley system to loop on wing spar; see Figure 5
    e. Level wing spar
    f. Place protractor on base of attachment point and measure to bottom edge of wing spar to determine beginning wing-spar angle; record beginning wing-spar angle on Student Supplement 2

       (NOTE: The beginning wing-spar angle will be used as a reference point for determining wing-spar failure. When the wing spar has been stressed to a point 15 degrees beyond the beginning angle, the wing spar will be considered to have failed.)
    g. Attach weight hanger to fishing-line loop and begin adding weights in small increments (ounces)
    h. Periodically remove weight hanger and weights and measure wing-spar angle
    i. Continue steps g and h until wing-spar angle measures 15 degrees beyond beginning wing-spar angle
    j. On Student Supplement 2, calculate combined weight of weights added to hanger when wing-spar failure occurs; record combined weight
    k. On Student Supplement 2, calculate strength-to-weight ratio of wing spar and record ratio
7. Report test results to your instructor
8. Clean work area and return equipment and materials to proper storage

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

UNIT OBJECTIVE

After completing this unit, the student should be able to list objectives of space-station construction, identify major structural elements of the space station, and plan and construct a model space station. The student will demonstrate these competencies by completing the assignment sheets, lab activity sheets, and the written test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with space-station construction to their correct definitions.
2. Match components of the construction system model to their correct definitions.
3. Define the term *construction technology*.
4. List objectives of space-station design.
5. Match major space-station structural elements to their correct definitions.
6. Discuss techniques to be used in space-station construction.
7. Investigate scientific uses of Space Station Freedom. (Assignment Sheet 1)
8. Plan productive and managerial processes for constructing a model of Space Station Freedom. (Assignment Sheet 2)
9. Construct a model integrated truss assembly. (Lab Activity Sheet 1)
10. Construct a complete model of the major structural elements of Space Station Freedom. (Lab Activity Sheet 2)

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

WRITTEN TEST

Name ______________________________ Score ______________

1. Match terms associated with airframe manufacturing to their correct definitions. Write the correct numbers on the blanks.

    _____a. Products that usually last fewer than three years

    _____b. Items taken from the earth, sea, and air

    _____c. Flexible, usually heatset, resin used chiefly in coatings and adhesives

    _____d. Engine and related parts that supply the power needed for forward motion in a self-propelled aircraft

    _____e. Group of people, procedures, equipment, and resources that function together to produce desired results

    _____f. Structure of an aircraft without the power plant

    _____g. Any of a group of synthetic materials fashioned into fibers, filaments, or sheets and used especially in textiles and plastics

    _____h. Permanent assembly method in which two or more materials are combined using pressure, heat, or glue or some other bonding agent

    _____i. Material in which something is enclosed or embedded

    _____j. Products that usually last at least three years

    _____k. Soft, black, lustrous carbon

    _____l. Strong plastic resin developed to withstand extremely high temperatures

    1. System
    2. Durable goods
    3. Nondurable goods
    4. Natural resources
    5. Airframe
    6. Power plant
    7. Aramid
    8. Graphite
    9. Matrix
    10. Epoxy resin
    11. Bonding
    12. Polyimide resin

WRITTEN TEST

2. Match components of the manufacturing system model to their correct definitions. Write the correct numbers on the blanks provided.

______a. Customer response, profit and loss, and quality control

______b. Natural resources, finance, capital, government standards, energy, human resources, and knowledge

______c. Durable and nondurable goods or products

______d. Management practices, production processes, and personnel practices

1. Inputs
2. Processes
3. Outputs
4. Feedback

3. Define the term *manufacturing technology*. Write your definition on the blanks below.

Manufacturing technology ____

____

____

____

4. Describe NASA's role in aeronautics manufacturing technology. Write your description on the blanks below.

NASA's role ____

____

____

____

5. Define the term *composite material*. Write your definition on the blanks below.

Composite material ____

____

____

____

WRITTEN TEST

6. Distinguish between descriptions of the types of bonding processes used in manufacturing composite materials. Write "CB" in the blank before the description of cohesive bonding and "AB" before the description of adhesive bonding.

    ______a. Process of permanently fusing two or more like materials by melting or softening the materials through the use of heat, pressure, or a solvent

    ______b. Process of using glue or cement to adhere the surfaces of two or more like or unlike materials

7. Match the major types of composite materials used in airframe manufacturing to their correct definitions. Write the correct numbers on the blanks provided.

    ______a. Layers of materials that are adhesive-bonded to form sandwich-type panels

    ______b. Complex materials in which graphite, glass, or aramid fibers are arranged in a matrix—generally epoxy or polyimide resin—and then heated under pressure to form a cohesively bonded substance that is strong but light and has a great resistance to corrosion and fatigue

    1. Advanced fiber composites
    2. Aluminum-honeycomb laminate composites

COMPOSITE MATERIALS IN AIRFRAME MANUFACTURING
UNIT III

WRITTEN TEST ANSWERS

1. a. 3
   b. 4
   c. 10
   d. 6
   e. 1
   f. 5
   g. 7
   h. 11
   i. 9
   j. 2
   k. 8
   l. 12

2. a. 4
   b. 1
   c. 3
   d. 2

3. Development of more efficient processes and materials to produce better manufactured products

4. To develop the technology needed to assure safer, more efficient, economical, and environmentally acceptable air-transportation systems

5. Product produced by bonding two or more materials to form a new and better material for a specific application

6. a. CB
   b. AB

7. a. 2
   b. 1

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

SUGGESTED ACTIVITIES

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review teaching suggestions given in the "Delivery and Application" section and plan classroom activities. Also note suggestions for media and supplemental materials.

  Plan presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit. See ordering information in the "Suggested Resources" section. Prepare transparencies. See Transparency Masters 1, 2, and 3.

- Obtain competency profiles for this unit. See ordering information in the "Suggested Resources" section.

- Prepare classroom and lab. Put up posters, charts, and signs; display articles related to the objectives of this unit.

- Carefully review Lab Activity Sheet 1, "Construct a Model Integrated Truss Assembly." Notice that this activity uses plastic building components from a set manufactured by Ramagon Toys, Inc., Portland, Oregon. You may choose to use other materials to complete this activity; however, if you are interested in purchasing the Ramagon components, write or phone Ramagon Toys using the following information.

  Mailing address: Ramagon Toys, Inc.
  618 N.W. Glisan Street
  Suite 205
  Portland, OR 97209

  Phone: (503) 224-5970

  To complete Lab Activity Sheet 1, you will need to purchase one "Very Big Builder" set, at a cost of approximately $50 dollars.

- Carefully review Lab Activity Sheet 2, "Construct a Complete Model of the Major Structural Elements of Space Station Freedom." Note that there is no step-by-step procedure for this lab activity sheet. In Assignment Sheet 2, "Plan Productive and Managerial Processes for Constructing a Model of Space Station Freedom," students will be divided into three groups and they will be required to plan the assembly of the space-station model. In Lab Activity Sheet 2, students should use the assembly plan they develop in Assignment Sheet 2. Teacher Supplement 2, "Space Station Freedom Model Plan," has been provided for your use in helping students complete this planning assignment and assembly activity.

You may choose to use other materials to complete this activity; however, if you are interested in purchasing the Ramagon components, you will need the following information.

To build one Space Station Freedom baseline model using the Ramagon components, you will need

- Two "Very Big Builder" sets (order number 10112), at a cost of approximately $50 per set, and
- One "Special Long-Rod Package" (order number 20210), at a cost that will be quoted by the company upon request.

Delivery and Application

Unit introduction

- Provide students with objective sheet. Discuss unit and specific objectives.
- Make copies of Teacher Supplement 1 and present the information in this supplement as an historical perspective of the development of the space-station concept. Use Transparencies 1, 2, and 3 to illustrate your presentation.

Objective 1 Match terms associated with space-station construction to their correct definitions.

Objective 2 Match components of the construction system model to their correct definitions.

Objective 3 Define the term *construction technology*.

- Treat these three objectives as a unit reviewing information students have already been acquainted with in the basic technology-education curriculum. Explain that in this unit students will explore how these basic construction concepts can also be applied in the air and space program—specifically as they relate to the future construction of Space Station Freedom.

Objective 4 List objectives of space-station design.

Objective 5 Match major space-station structural elements to their correct definitions.

SUGGESTED ACTIVITIES

Objective 6 Discuss techniques to be used in space-station construction.

- Treat objectives 4, 5, and 6 as a unit describing the sequence in the developmental phases of the space-station concept. Relate to students that establishing objectives of the space station was the first step and that these objectives have guided NASA's direction in the next two steps—overall structural design and construction techniques to be used in completing the project.

- Review with students the introduction to Assignment Sheet 1, "Investigate Scientific Uses of Space Station Freedom." Discuss with students possible sources of information for them to use in completing this assignment. For example, introduce students to *Station Break*, the bimonthly newsletter on the Space Station Freedom program. Have students complete Assignment Sheet 1.

- Help students locate Lab Activity Sheet 1, "Construct a Model Integrated Truss Assembly," and Student Supplement 1, "Lab Activity 1 Worksheet." Read with students the introduction to the lab activity and demonstrate the procedure. Discuss with students the use of the worksheet. Have students complete Lab Activity Sheet 1.

- Help students locate Student Supplements 2, 3, and 4: "Assembly," "Futuristic Perspective," and "Management." Assist students in outlining the information presented in these student supplements.

  In Student Supplement 2, be sure that students are able to outline what will take place during each of the four major steps in the assembly sequence of the space station: (1) First-element launch, (2) Man-tended capability, (3) Permanently manned capability, (4) Assembly complete.

  In Student Supplement 3, be sure that students understand the concept of hooks and scars engineering.

  In Student Supplement 4, be sure that students can outline the duties of each of the three tiers in the management structure NASA utilizes in planning construction of the space station.

- Divide the students into three groups: Level 1—Policy and Overall Program Direction, Level 2—Program Management and Technical Content, and Level 3—Project Management. Explain that these three groups will work together to plan and then construct a model of Space Station Freedom, following the productive and managerial processes students have studied in Student Supplements 2, 3, and 4.

SUGGESTED ACTIVITIES

Read with students the introduction to Assignment Sheet 2, "Plan Productive and Managerial Processes for Constructing a Model of Space Station Freedom."

Have students complete the exercise in Assignment Sheet 2. Use Teacher Supplement 2 to help you help students during these planning stages. At the end of this assignment, the class members should have cooperated to develop one plan for the management and assembly sequence for the single space-station model their class will produce in Lab Activity Sheet 2, "Construct a Complete Model of the Major Structural Elements of Space Station Freedom."

- Read with students the introduction to Lab Activity Sheet 2. Do not demonstrate a procedure for completing this lab activity. Have students follow the plans they have developed for constructing their model of the space station. Provide them with guidance as necessary in completing this lab activity, but let them remain somewhat independent—the purpose of this activity is to allow students to learn to plan and follow through on those plans even if a part of that activity is to learn to profit from their mistakes.

Evaluation

- Give written test.
- Compile written-test, assignment-sheet, and lab-activity-sheet scores.
- Reteach and retest as required.

Suggested Resources

Resources used in developing unit

Print media

- *Space Station Freedom Media Handbook.* Washington, D.C.: Office of Space Station, NASA Headquarters, April 1989.

  This handbook is intended to be an easy-to-read, useful reference guide for the Space Station Freedom program. The book is in the public domain—you may use any and all information and art in it without permission, and you may request additional publications or quality photos from the contacts listed in the Appendices.

SUGGESTED ACTIVITIES

Additional copies in reasonable quantities may be ordered from

Mark Hess
Public Affairs Officer
Office of Space Station
NASA Headquarters
Washington, D.C. 20546-0001

Resources to be used to supplement unit materials

Print materials

- *Station Break*. Washington, D.C.: NASA Technical and Administrative Services Corporation (TADCORPS).

  Station Break is a bimonthly newsletter on the Space Station Freedom program. Articles and artwork from the newsletter may be reproduced without permission. Those wishing to be added to the *Station Break* mailing list should place their requests in writing on business letterhead to the editor at the following address:

  Lee Ann Landers
  Station Break/TADCORPS
  600 Maryland Avenue, SW, #200
  Washington, D.C. 20024

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

TEACHER SUPPLEMENT 1—HISTORICAL PERSPECTIVE

The concept of the space station goes back at least to 1869 when Edward Everett Hale mentioned in the *Atlantic Monthly* the "Brick Moon," a 60-meter-diameter satellite for a crew of 37 to help navigate ships at sea. Novelists like H.G. Wells and Jules Verne foresaw space travel in the late 1800s. By the turn of the century, scholars such as Konstantin E. Tsiolkovsky were laying the foundations of space travel to orbital stations.

The modern space-station concept dates back to 1923, when the Romanian-born Hermann Orberth published his theoretical treatise on the possibilities of large, liquid-fueled rockets. *Die Rakete zu den Planetenraumen* (The Rocket to Interplanetary Space) was the opening shot in a debate about the meaning of the space station that was to last for more than six decades. Oberth envisioned a voyage to Mars, and perceived that a refueling depot in outer space (or "weltraumstatin") would serve as a staging point for the journey. He quickly realized that a station in space could do many other things that would further justify its construction.

In the 1920s, other visionaries, mostly Germans, joined Oberth in his advocacy of this unheard-of technology. A space station was, at this time, symbolic of a wide range of Earth-orbital activity, such as astronomy, meteorology, cartography, and military reconnaissance. The word "weltraumstation" became a short-hand description for the entire gamut of orbital spaceflight technology.

Wernher von Braun was one such young enthusiast. A protege of Oberth, he rose in the 1930s to become the premier rocket designer/engineer of his time. Unfortunately, the cost of building a rocket—the first logical step into space—was so high that the only patron available was the state of Nazi Germany. Von Braun saw the V2 as an intermediate step toward the much grander vision of a manned mission to Mars. He and other visionaries, such as Krafft Ehricke, left Germany at war's end to work for the United States. Thus, serious space-station thinking came to the United States in 1945.

In the 1950s, many groups began to think of the immediate and practical uses of space—both civilian and military. Von Braun was in the forefront of the space race, but he dreamed of a space station in permanent Earth orbit that would satisfy a wide range of scientific, economic, and political objectives—and serve as a base for future missions to the Moon and to Mars. He postulated that to get to that step, the United States should first build a small test-bed orbital laboratory. Others agreed in principle, and the debate continued: How long should such an orbital laboratory last? What was its primary function—to test man, or technology, or both? How many crew? Would it be resupplied? What altitude and inclination? Should it be built in space or on the ground and deployed in space?

NASA, created in 1958, became the forum for the space-station debate. In 1960, space-station advocates from every part of the fledgling space industry gathered in Los Angeles for a Manned Space Station Symposium, where they agreed that a space station was a logical goal but disagreed on what it was, where it should be put, and how to build it.

In 1961, President Kennedy decided that the Moon was a target worthy of the American spirit and heritage. A lunar landing had an advantage over a space station: Everyone

TEACHER SUPPLEMENT 1

could agree on the definition of landing on the Moon, but few could agree on the definition of a space station. This disagreement was healthy. It forced station designers and advocates to think about what they could do, the cost of design, and what was necessary. What were the requirements for a space station? How could they best be met? The requirements review process started informally in 1963 and continued for 23 years. NASA officials asked the scientific, engineering, and business communities over and over again—What would you want? What do you need? The answers flowed in, and NASA scientists and engineers puzzled over how to organize these wants and needs into an orderly, logical sequence of activity. Was the station a laboratory, observatory, industrial plant, launching platform, or drydock? If it were all of these things, how much crew time should be devoted to each?

In the 1960s, working quietly in the shadow of the gigantic Apollo/Saturn program, space-station designers and planners began to come to grips with the tough questions of safety, hardware, money, and manpower. Working from 1964 through 1966, they settled on the modular approach: a pay-as-you-go program that offered something to everyone. With incremental funding, NASA managers could provide an incremental space station. Yet cost remained a problem. Design costs were always eclipsed by operations costs. The longer a station stayed up in space, the more it would cost to operate and resupply.

In 1967 and 1968, NASA planners started looking at an advanced logistics-vehicle concept for the space station. They already had a dependable transportation system (the Saturn rocket) to launch station modules. What they needed was a relatively inexpensive way to resupply the station. This reusable spacecraft would shuttle between Earth and the space station. Hence, the word "shuttle" was selected in the summer of 1968.

NASA officials felt that the station/shuttle combination served everybody's needs. The station had always been a logical step into space. The problem was that not everyone in the country agreed that developing space technology was a logical thing to do. The station program was caught in the shifting ties of politics and culture. Furthermore, the station and the shuttle began to be perceived as two separate entities, which had not been anyone's original intention. In 1970, plans to launch modules via Saturn technology were cancelled, and station designers were told to scale down their modules to fit inside the shuttle, which would now do double duty as launch and resupply vehicle.

Thus, in 1972, in the approval of a reusable space transportation system, the space-station concept itself was approved. The transportation segment, called the Space Shuttle, would be developed first. The space station itself would await the future. But before the Shuttle could be developed and made operational for a space station, the Saturn rocket would be used as both launch vehicle and the spacecraft for America's first space station: Skylab.

Skylab was launched in 1973 and served as the test-bed for the first American experiments in long-duration, manned spaceflight. Even though Skylab had a short life and was not equipped for resupply of key expendable items, it did foreshadow the promise of a permanently manned laboratory in space. The Skylab effort proved humans could live and work in space for extended durations, and more than 100 different experiments in life and materials science, earth and solar observation were conducted successfully.

With the first flight of the Space Shuttle, in April of 1981, a space station was again considered as the next logical step in manned spaceflight. In May of 1982, a Space Station Task Force was formed, and a year later they had an initial space-station concept.

TEACHER SUPPLEMENT 1

Cabinet-level departments and agencies studied the concept, and in January of 1984, President Reagan committed the nation to the goal of developing a permanently manned space station within a decade.

The Space Station Program Office was established in April of that year, and in April of 1985, eight contractors were selected to develop a detailed definition of the space station. In March of 1986, the Systems Requirements Review settled on a dual-keel configuration for the space station, affording a better microgravity environment, more capacity for attached payloads, and better location for the servicing bay than a single transverse boom. The U.S. reduced the number of their laboratory modules to one when the Europeans and Japanese decided to provide one each.

Although the definition and preliminary design phase ended in January 1987, the remainder of the year was spent conducting cost analysis, review of technical design issues, developing procurement packages, reviewing science requirements, developing operations concepts, and reporting to Congress and commissions. The Development Contracts were announced in December 1987. These efforts resulted in the baseline configuration that is discussed in this unit.

Reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

TEACHER SUPPLEMENT 2—SPACE-STATION FREEDOM MODEL PLAN

The following information is provided for your use in helping students complete the planning exercises in Assignment Sheet 2, "Plan Productive and Managerial Processes for Constructing a Model of Space Station Freedom," and the assembly activity in Lab Activity Sheet 2, "Construct a Complete Model of the Major Structural Elements of Space Station Freedom."

The major structural elements of Space Station Freedom will consist of the following:

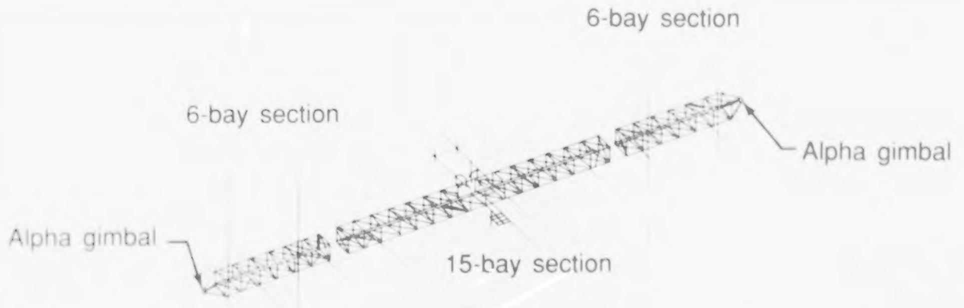
- Integrated truss assembly
- United States Habitation Module
- United States Laboratory Module
- ESA Columbus Laboratory Module
- Japanese Experiment Module
- Logistic elements
- Resource nodes
- Photovoltaic power arrays
- Thermal radiators
- Mobile Servicing Center
- Space Shuttle

Plan for completion of the model integrated truss assembly

In Lab Activity Sheet 1, "Construct a Model Integrated Truss Assembly," students will build and then test a 7-bay integrated-truss assembly. From this lab activity, students will learn the basic construction techniques necessary to complete the 27-bay truss that is required for the model space station. However, they will still need to make an assembly plan for creating the 27 bays. NASA's actual assembly plan for Space Station Freedom's truss is shown below in Figure 1 (and is also shown in the student material in Figure 2 of the introduction to Lab Activity Sheet 1). NASA's plan calls for a three-stage assembly consisting of two 6-bay outer sections and one 15-bay central section, which will be combined to form a 27-bay structure.

Using Ramagon building components or other materials of your choice, have the class construct the 27-bay structure first and then attach alpha gimbals (see Lab Activity Sheet 1) at each end to complete the model truss assembly. See Figure 1.

FIGURE 1



TEACHER SUPPLEMENT 2

Plan for figuring the scale of the structural elements

Once the truss assembly is completed, have students use the completed length of the assembly as a basis for figuring the scale of the remaining structural elements.

1. Have students measure the length of the model truss and then convert the measurement to inches, if necessary. Our completed truss model using the Ramagon components measured 9.5 feet, which converts to 114 inches, or

   9.5 feet × 12 inches/foot = 114.00 inches.

2. The actual length of the full-scale space station will be 508 feet. Convert this measurement to inches, or

   508 feet × 12 inches/foot = 6096 inches.

3. Divide the actual length of the space station (in inches) by the length of the model (in inches) to determine the scale of the actual truss to the model, or

   $$\frac{6096 \text{ inches}}{114 \text{ inches}} = 53.5, \text{ or}$$

   The scale of the actual truss to the model would be 1:53.5 (1 inch on the model equals 53.5 inches on the actual space station).

4. To calculate the scale size of each of the other model elements, use the following formula:

   (Actual length of element in ft. × 12 in./ft.) ÷ 53.5 = Scale size of element.

5. Actual dimensions of the various space-station elements are given in Table 1 below.

TABLE 1: Actual dimensions of space-station structural elements

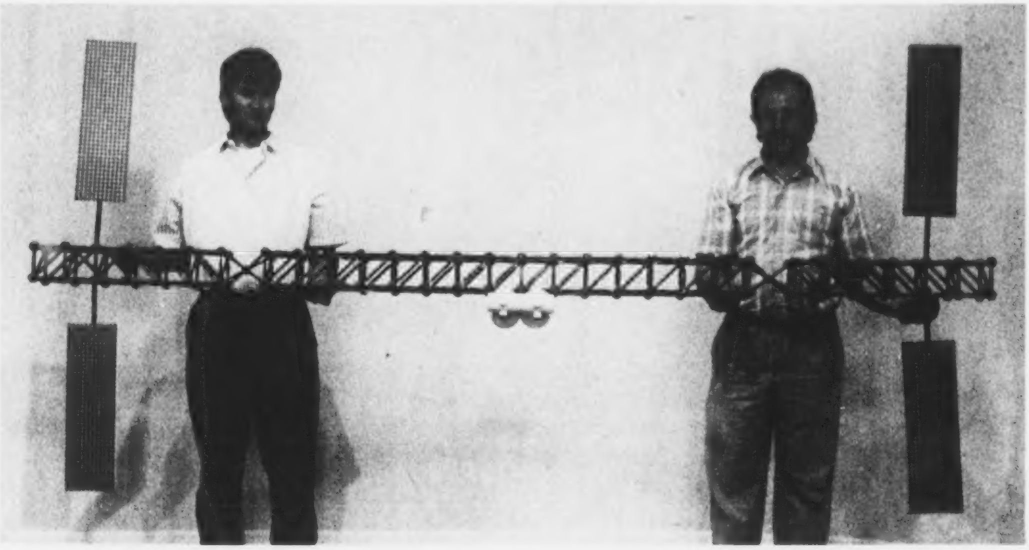
Element	Actual dimension
Integrated truss assembly	508 feet
U.S. Habitation Module U.S. Laboratory Module	44 feet long, 14 feet in diameter
ESA Columbus Laboratory Module	13 feet in diameter
JEM pressurized module	32 feet long, 13 feet in diameter
Logistic elements	14 feet in diameter, lengths will vary
Resource nodes	17 feet long, 14 feet in diameter
Photovoltaic power arrays	108 feet long, 34 feet wide
Thermal radiators	50-foot square
Mobile Servicing Center	20 feet long, 16 feet wide, height not yet determined
Space Shuttle	121 feet long with a wing span of 79 feet

TEACHER SUPPLEMENT 2

Equipment and materials listing

The following is a listing of the materials we used to construct the integrated truss assembly, lab and habitation modules, and power arrays shown in the partially completed space-station model in Figure 2.

FIGURE 2



Lab and habitation modules

- Cardboard tubing
- PVC pipe
- Dowel rods
- Posterboard
- Cardboard

Solar array

- Cardboard
- Contact paper
- ¼-inch balsa wood
- Posterboard

Other tools and equipment

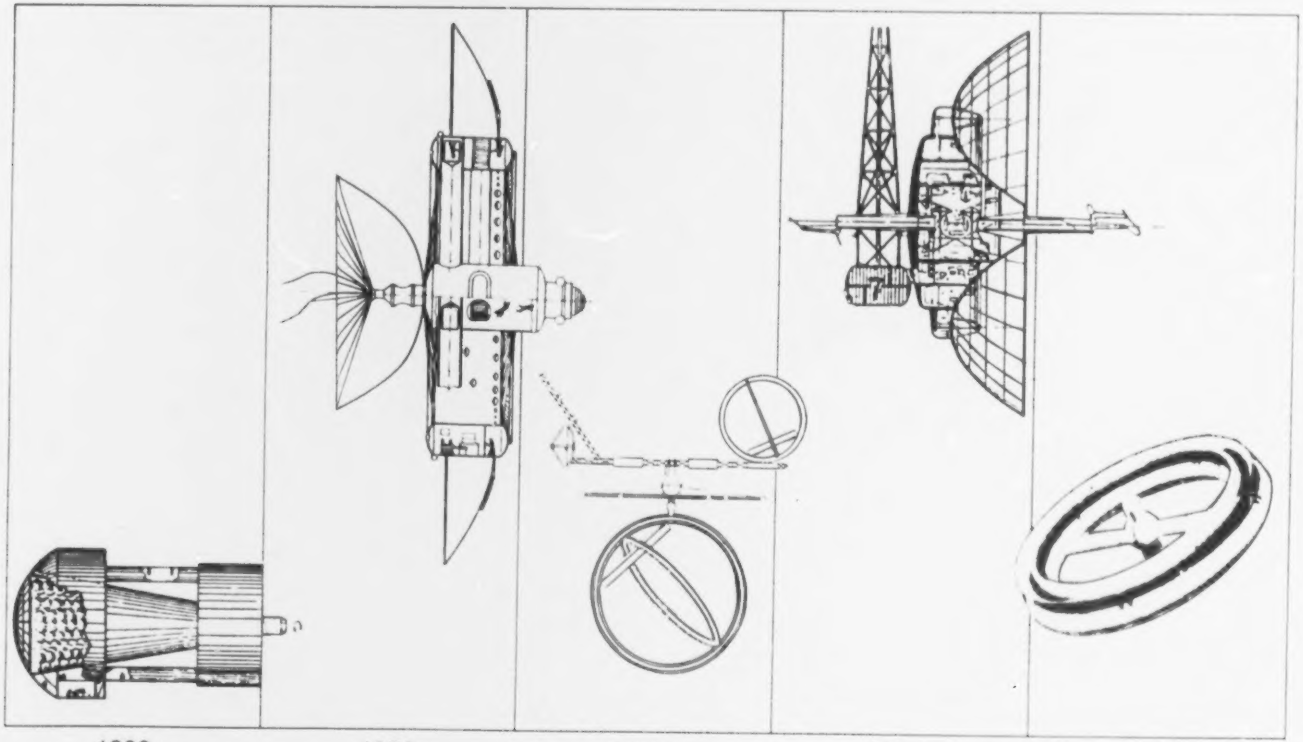
- Glue
- Disc sander
- Belt sander
- Band saw
- Hot-glue gun
- Fishing line

Integrated truss assembly

- Two "Very Big Builder" sets
- One "Special Long-Rod Package"

These components were ordered from Ramagon Toys, Inc., Portland, Oregon. See ordering information in the Suggested Activities section.

Early Space-Station Concepts



1900s
Konstantin Tsiolkovsky

1920s
Hermann Noordung

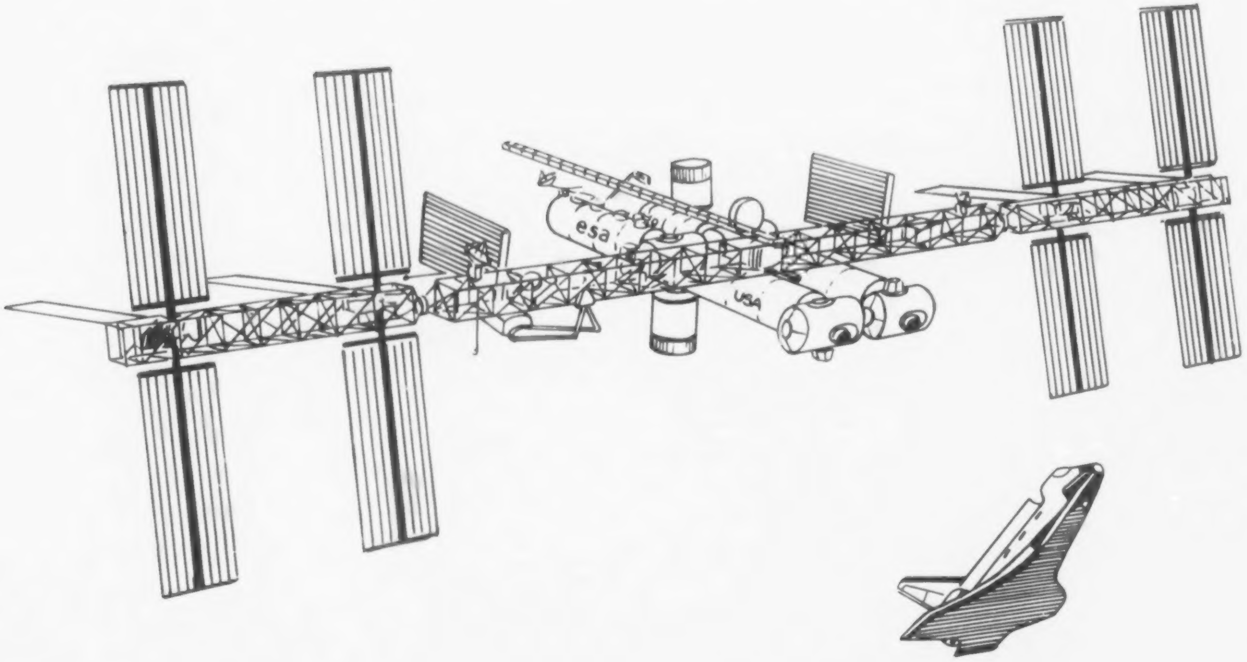
1930s
Hermann Oberth

1940s
Harry E. Russ and
Ralph A. Smith

1950s
Werner von Braun
Chesley Bonestell

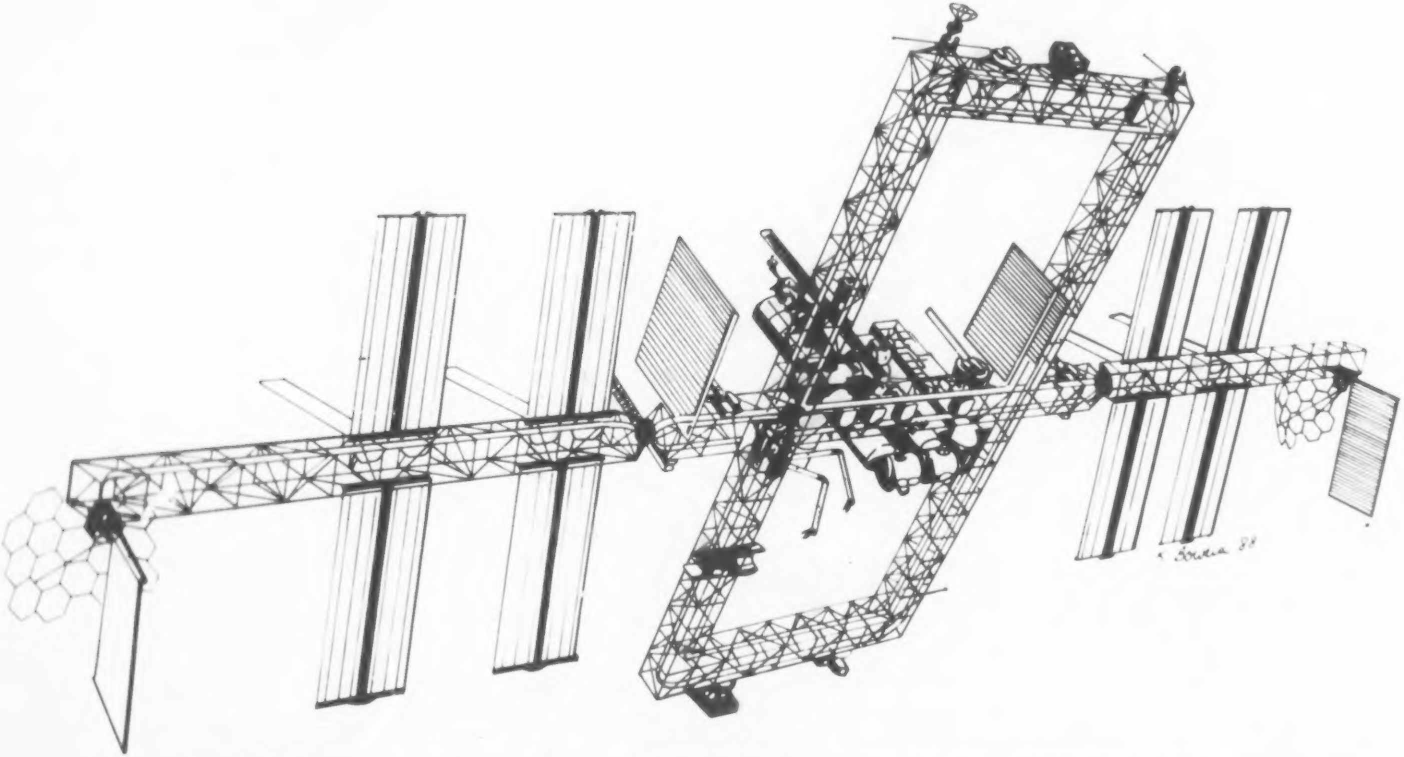
Reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Space Station Freedom—Baseline Configuration



Reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Space Station Freedom—Enhanced Configuration



Reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

INFORMATION SHEET

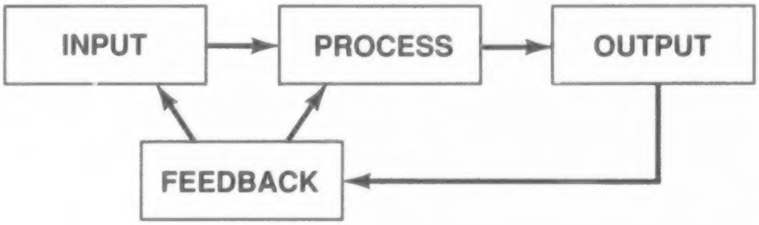
1. **Terms and definitions associated with space-station construction**

   a. **Construction**—Production of a structure on site

   b. **Structure**—Something made up of a number of parts that are held or put together in a particular way

2. **Components of the construction system model and their definitions** (Figure 1)

   FIGURE 1



Universal system model

   a. Inputs—People, knowledge, materials, energy, capital, and money

   b. Processes

      (1) Productive—Preparing to build, designing the project, building the structure, installing systems, finishing the structure, completing the site and closing the contracts, and servicing the project

      (2) Managerial—Planning, organizing, directing, and controlling

   c. Outputs—Structure

      Example: Space Station

   d. Feedback—Customer/user response, profit and loss, and quality control

INFORMATION SHEET

3. **Definition of the term *construction technology***—Effective use of materials, labor, equipment, methods, and management resources to produce a structure on site

4. **Objectives of space-station design**

   (NOTE: The following objectives for Space Station Freedom were based upon the needs expressed by many potential users over a six-year design phase. These objectives have guided NASA's overall activities on the project and have given direction to the technical analysis necessary to complete the overall design of the project. Upon completion, this multipurpose station will meet a wide range of NASA mission requirements as well as those of other federal agencies, private organizations, and foreign governments.)

   Space Station Freedom will be

   a. A *laboratory* for conducting scientific research and developing new technologies

   b. A *permanent observatory* to look down upon the Earth and out into the universe

   c. A *servicing/repair facility* where payloads and spacecraft are resupplied, maintained, upgraded, and repaired

   d. An *assembly facility* where large payloads and vehicles are stationed, processed, and launched to their destinations

   e. A *manufacturing facility* where space-age products can be made

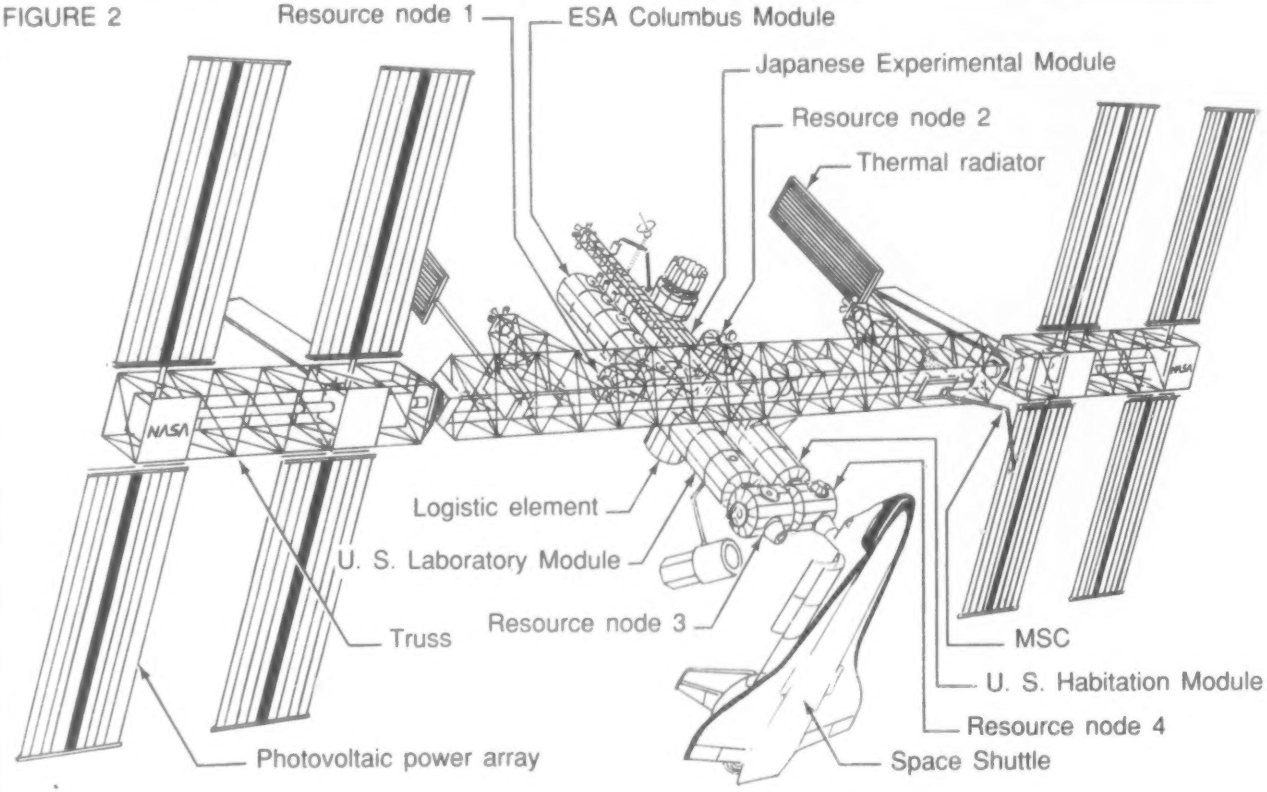
   f. A *storage depot* where payloads and parts are kept in orbit for subsequent deployment

   g. A *staging base* for future endeavors in space, such as a lunar laboratory or a base on Mars

INFORMATION SHEET

5. **Major space-station structural elements and their definitions** (Figure 2)

FIGURE 2


Resource node 1
ESA Columbus Module
Japanese Experimental Module
Resource node 2
Thermal radiator
NASA
NASA
Logistic element
U. S. Laboratory Module
Truss
Resource node 3
MSC
U. S. Habitation Module
Resource node 4
Space Shuttle
Photovoltaic power array

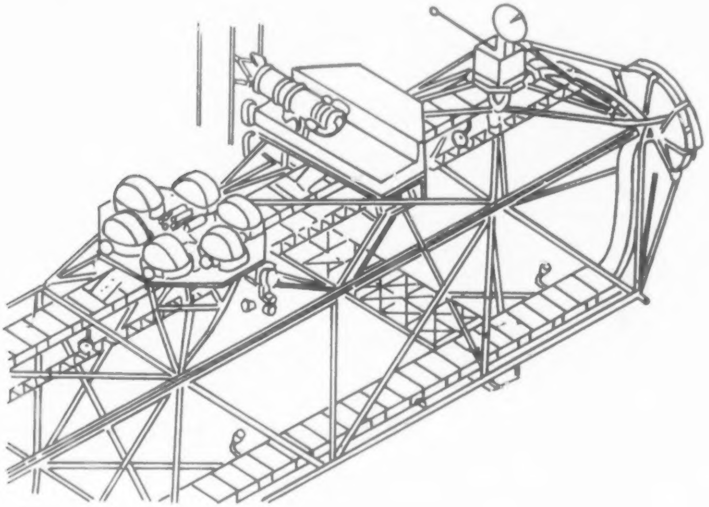
Baseline configuration—Space Station Freedom

Reprinted with permission of the National Aeronautics and Space Administration, from *The Space Station Power System*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., n.d.

INFORMATION SHEET

a. **Integrated truss assembly**—Framework and attachment point for other space-station elements (Figure 3)

FIGURE 3



Integrated truss assembly

Reprinted with permission of the National Aeronautics and Space Administration, from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

(NOTE: The integrated truss assembly will provide the framework for the core base of the space station. It will serve as the attachment point for the photovoltaic power arrays, as well as other systems, including experiments. It will also facilitate the movement of crew and equipment, and provide for distributed systems.)

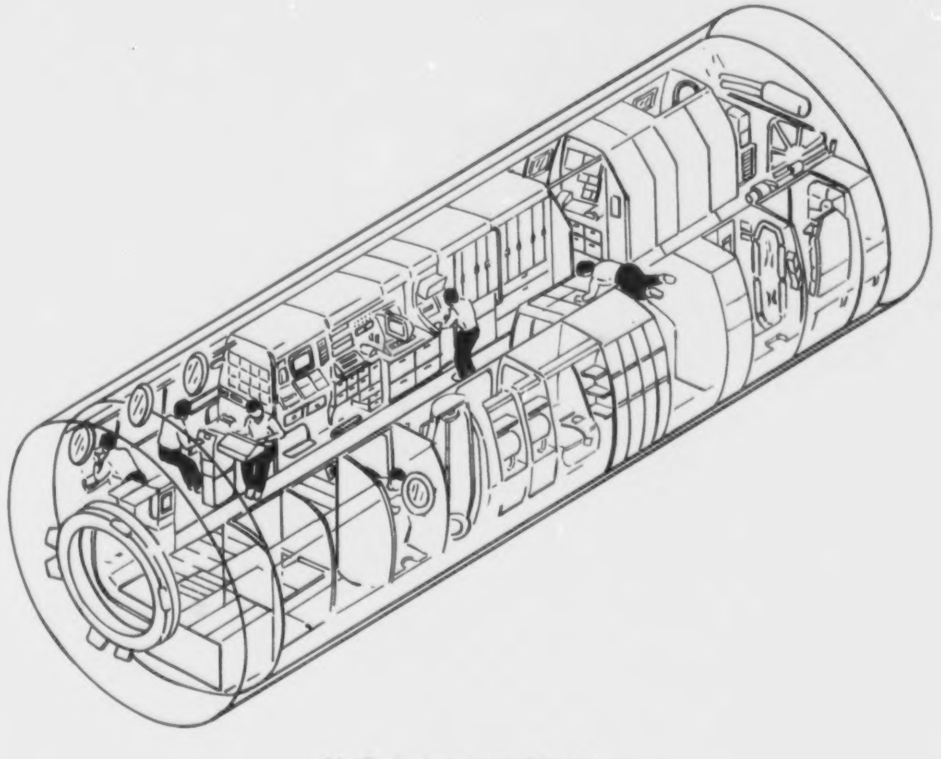
b. **Laboratory and habitation modules**—Pressurized cylinders to provide astronauts with living quarters and research centers for conducting materials research, life-sciences research, and other space-science investigations

(NOTE: In all, there will be four pressurized modules. The United States will provide one habitation module and one laboratory module; Japan and the European Space Agency [ESA] will each provide two other laboratory modules.

Equipment in the U.S. Laboratory Module will include furnaces for growing semiconductor crystals, electrokinetic devices for separating pharmaceuticals, support equipment for low-gravity experiments, and a centrifuge for variable-gravity experiments in life sciences. The U.S. Habitation Module will provide up to eight astronauts with quarters for eating, sleeping, personal hygiene, waste management, recreation, and health maintenance. See Figure 4.

INFORMATION SHEET

FIGURE 4



U. S. Laboratory Module

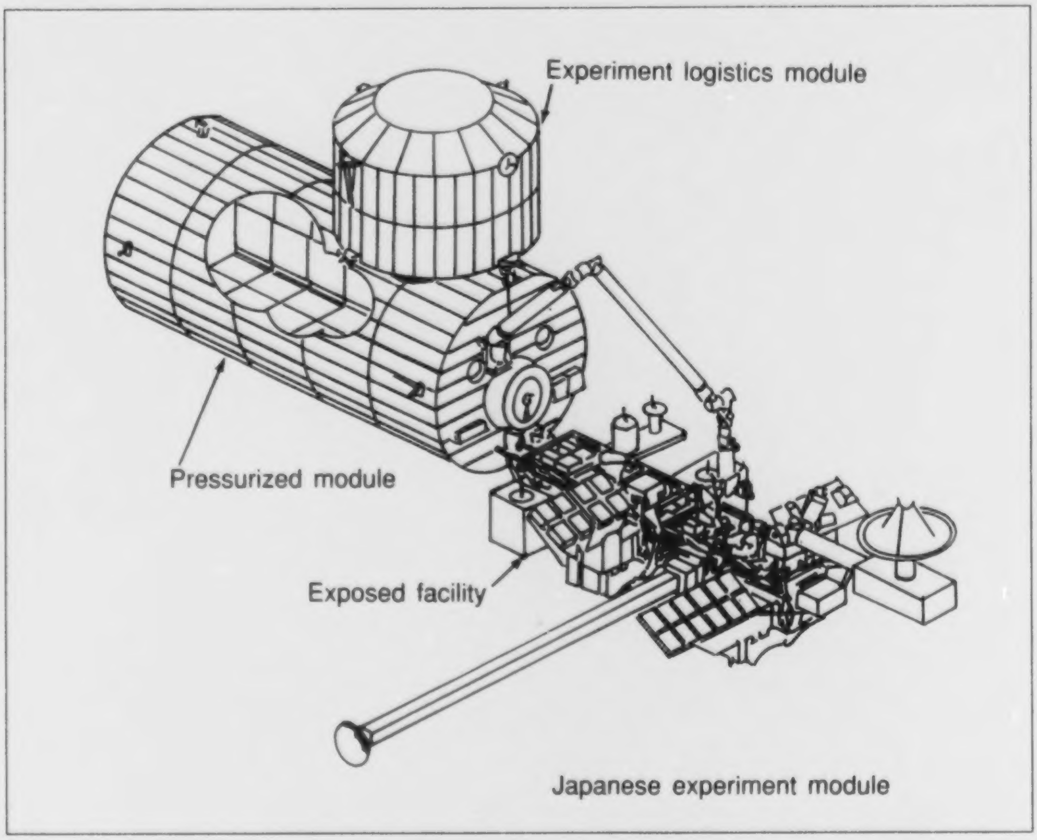
Reprinted with permission of the National Aeronautics and Space Administration, from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

The ESA's Columbus Laboratory Module will be permanently attached to the space station's manned base. It will be used primarily for materials sciences, fluid physics, and compatible life-sciences missions.

The Japanese Experiment Module [JEM] will be a multipurpose laboratory consisting of three components: a pressurized module, an exposed facility, and an experiment logistics module. Materials-processing experiments and life-science experiments will be performed in the pressurized module and it will also be the control and monitoring center for experiments performed on the exposed facility. Scientific observation, communication experiments, scientific/engineering, and materials experiments will be conducted on the exposed facility. The Experiment Logistics Module will provide on-orbit storage and a means of transporting logistics supplies such as experiment specimens, gases and fluids, equipment and space parts for maintenance. See Figure 5.)

INFORMATION SHEET

FIGURE 5



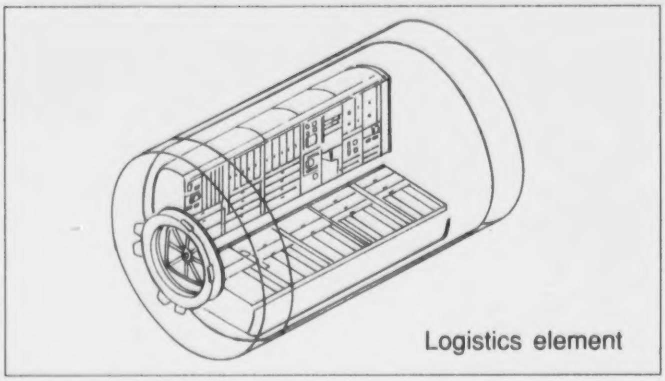
Reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

c. **Logistics elements**—Replaceable cargo canisters attached to the station truss or to a module and designed to fit into the cargo bay of the Space Shuttle to transport equipment, supplies, and fluids to the station and to return experiment results, equipment, and waste products back to Earth

(NOTE: The space station will require two kinds of logistics elements: pressurized and unpressurized. Pressurized logistics carriers [PLCs] will carry items requiring a habital environment. PLCs will transport life-science specimens [plants, etc.] to the station and then transport equipment, products, plants, biological specimens, and waste from the station. Unpressurized logistics carriers [ULCs] will transport payloads and equipment that do not need a pressurized environment. Typical contents in the ULCs will include platforms, payloads, and experiments for the station and fluids for the crew. See Figure 6.)

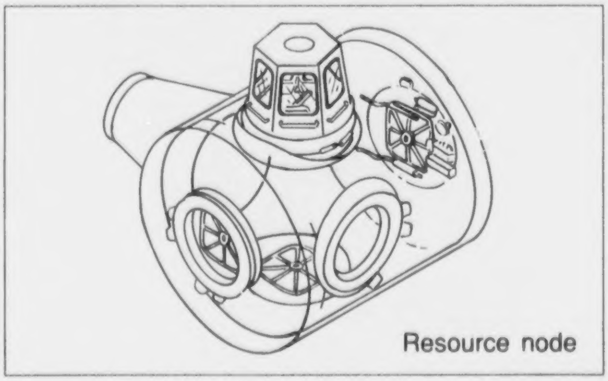
INFORMATION SHEET

FIGURE 6



d. **Resource nodes**—Pressurized cylinders designed to serve as command and control centers and as passageways to and from modules (Figure 7)

FIGURE 7



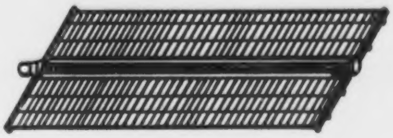
Figures 6 and 7 reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

(NOTE: The space station will contain four resource nodes. Although the final configuration of the four nodes has not been determined, in the design stage they were located as follows. Node 1 will be the control center for both unmanned flight and man-tended operations. It will be located between the U.S. Laboratory and ESA's Columbus Module. Node 2, located between the Habitation Module and the Japanese Experiment Module, will provide spacecraft and station back-up command and control work stations. Node 3 will likely be the primary command and central station for the pressurized modules and will be located at the forward end of the U.S. Laboratory Module. Node 4, connected to Node 3 and the forward end of the U.S. Habitation Module, will feature a cupola designed for proximity operations and berthing of the Space Shuttle.)

INFORMATION SHEET

e. **Photovoltaic power arrays**—Panels of solar cells designed to provide the electrical power needed for space-station operations (Figure 8)

FIGURE 8



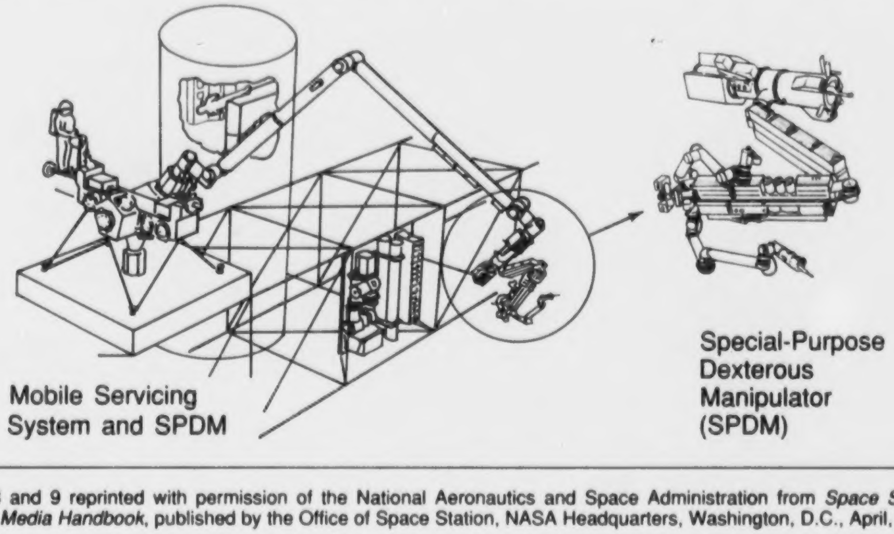
Power array

(NOTE: A series of eight power arrays will provide electric power aboard the space station during its early years. Each array will consist of two blanket assemblies, each covered with 14,592 solar cells.)

f. **Thermal radiators**—Panels designed to interface with the environmental-control and life-support systems to remove excess heat from the atmosphere of the pressurized modules and nodes (See Figure 2)

g. **Mobile Servicing Center** (MSC)—Rail-mounted center containing a robotic arm that will be moved along the truss to perform assembly and maintenance duties (Figure 9)

FIGURE 9


Mobile Servicing System and SPDM
Special-Purpose Dexterous Manipulator (SPDM)

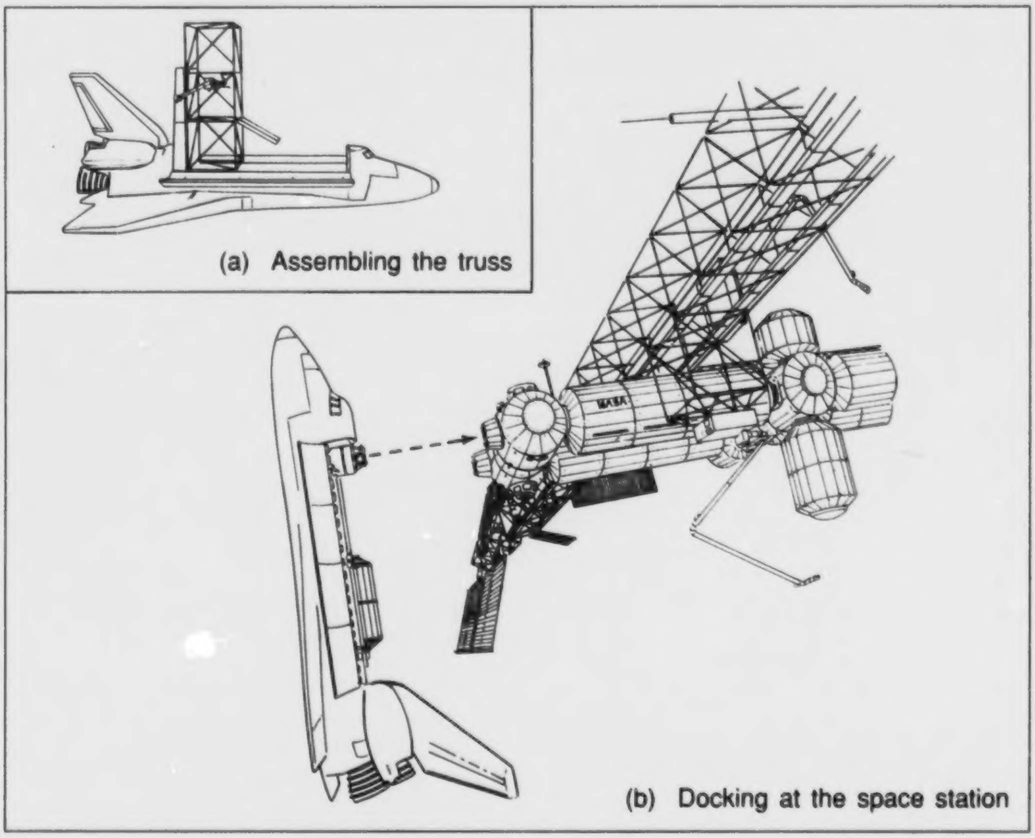
Figures 8 and 9 reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

INFORMATION SHEET

(NOTE: Together with a U.S.-provided rail-mounted mobile transporter, the robotic arm to be supplied by Canada will play the main role in Space Station Freedom's assembly and maintenance, moving equipment and supplies around the station, releasing and capturing satellites, supporting extravehicular activities, and servicing instruments and other payloads attached to the station. The MSC will also be used for docking the Space Shuttle to the station and then loading and unloading materials from its cargo bay.)

h. **Space Shuttle**—Vehicle to transport the materials for the initial assembly and checkout of the space station and later to provide continued roundtrip transportation for crews and supplies between the Earth and the space station (Figure 10-a and -b)

FIGURE 10



(a) Assembling the truss

(b) Docking at the space station

Figure 10-a reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

Figure 10-b reprinted with permission of the National Aeronautics and Space Administration from *Space Station: Leadership for the Future* by Franklin D. Martin and Terence T. Finn, published by the Office of Space Station, NASA Headquarters, Washington, D.C., August, 1987.

INFORMATION SHEET

6. Techniques to be used in space-station construction

a. On-earth construction—Resource nodes, laboratory and habitation modules, logistic elements, solar arrays, and thermal radiators will be constructed on Earth and transported into space by the Space Shuttle. They will be finished products before they are transported and will need only to be attached to the integrated truss assembly once in space

b. In-space construction—The beams for the integrated truss assembly will be manufactured on Earth, transported into space by the Space Shuttle, and then the integrated truss assembly will be constructed in space

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

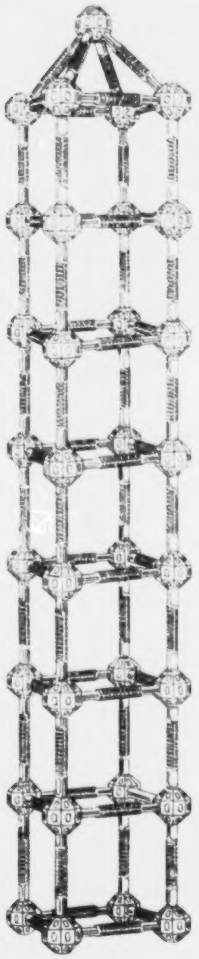
STUDENT SUPPLEMENT 1—LAB ACTIVITY 1 WORKSHEET

Name ______________________________

Directions After completing Procedure A in Lab Activity Sheet 1, conduct the following test procedure and then answer the questions below.

Test Procedure A Stand the 7-bay structure on floor as shown in Figure 1. Apply downward pressure at the alpha gimbal while carefully turning the structure left and right.

FIGURE 1



(NOTE: Do **not** break the Ramagon pieces by applying too great a downward pressure or twisting the structure too violently.)

1. Do you think that the design of this structure is structurally sound? (Circle your answer.) Yes No

   Explain your answer on the blanks provided below.

2. The *elastic limit* of a structure is the point beyond which the structure will suffer permanent deformation when subjected to a force. Do you think that this structure has a high or low elastic limit? (Circle your answer.) High Low

   Explain your answer on the blanks provided below.

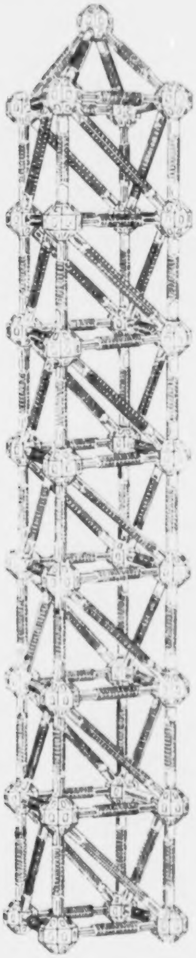
STUDENT SUPPLEMENT 1

Directions After completing Procedure B in Lab Activity Sheet 1, conduct the following test procedure and then answer the questions below.

Test Procedure B Stand the 7-bay truss structure on floor as shown in Figure 2. Apply downward pressure at the alpha gimbal while carefully turning the structure left and right.

(NOTE: Do **not** break the Ramagon pieces by applying too great a downward pressure or twisting the structure too violently.)

FIGURE 2



1. Do you think the design of this structure is stronger or weaker than the design of the structure tested above? (Circle your answer.) Stronger Weaker

   Explain your answer on the blanks provided below.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

2. Do you think that this structure has a high or low elastic limit? (Circle your answer.) High Low

   Explain your answer on the blanks provided below.

   ____

   ____

   ____

   ____

   ____

   ____

   ____

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

STUDENT SUPPLEMENT 2—ASSEMBLY

Introduction

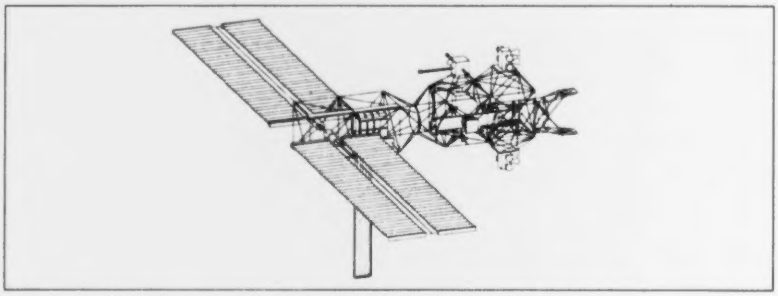
Space Station Freedom will weigh about half a million pounds and will be too large and heavy to be placed into orbit by one launch vehicle. Based upon the Shuttle's performance and payload-bay physical limitations, the current planning calls for approximately 20 Shuttle flights to get all of the elements, systems, and support equipment to low Earth orbit. This assembly process will take about four years. The sequence in which these flights occur and packaging of selected parts is dependent on many factors. Early planning of the assembly sequence was based on various criteria such as utilization, manning, safety, power, and microgravity levels. The following is a brief description of Space Station Freedom's major assembly milestones.

The Manned Base assembly sequence of 20 Space Shuttle flights has 4 major milestones. These events are planned to be accomplished close to the completion of the 1st, 4th, 13th, and 20th shuttle flights.

First-element launch (FEL)

The first cargo will consist of a set of integrated Space Station Freedom components to provide a fully functional spacecraft as the "cornerstone" for the fully assembled Manned Base. This "cornerstone" will be the starboard end of the Manned Base and includes a power module with solar panels and radiators, communications pallet with antenna, a reaction control system and tank farm, the mobile transporter, an assembly work platform, and associated truss and alpha joint structures. This integrated assembly will provide its own power and heat rejection, adequate orbital life, communications with the ground, and the capability to rendezvous and dock with the Space Shuttle for subsequent assembly flights. See Figure 1.

FIGURE 1

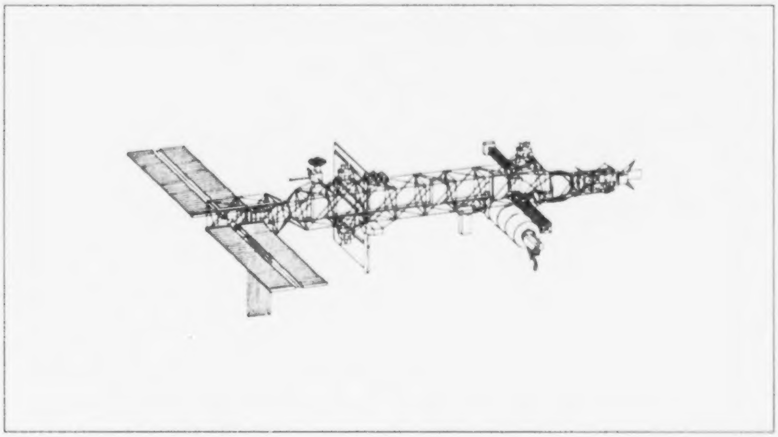


STUDENT SUPPLEMENT 2

Man-tended capability (MTC)

Upon completion of the 4th assembly flight, added structure will extend to the approximate center of the Manned Base and include the first-phase Mobile Servicing Center, a pressurized docking module, and the U.S. Laboratory Module outfitted to accommodate experiments. These added components and elements (see Figure 2) will provide the Manned Base with an early man-tended capability until the next phase, permanently manned capability (PMC). The conduct of science and technology development in the U.S. Lab Module will be tended by astronauts on succeeding Shuttle assembly flights.

FIGURE 2



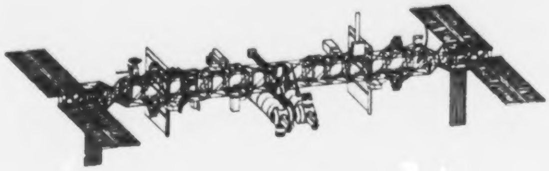
Permanently manned capability (PMC)

Upon completion of perhaps the 11th assembly flight, the complementing port side of the structure and components will have been added, including the inboard power module with solar panels and radiator, tank farm, reaction control module, and logistics modules, attached payloads and equipment from the extended-duration orbiter flights, aft and forward nodes with cupolas, airlocks, and the Habitation Module. See Figure 3.

Initial crew size will be at least four persons and will grow to eight when the international modules are attached. The crew will have the capability to live and work comfortably and safely in pressurized volumes indefinitely, and be able to perform full space-station-based extra vehicular activities (EVAs). PMC will mark the beginning of full-scale Manned Base operations on a day-to-day basis.

STUDENT SUPPLEMENT 2

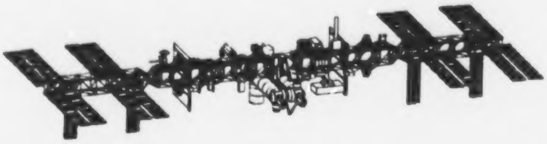
FIGURE 3



Assembly complete

Upon complete assembly of the Manned Base (see Figure 4), the Space Station Freedom Program will be a fully international space operation. The Japanese Experiment Module and the ESA Laboratory Module will be attached, and the Canadian Mobile Servicing Center will be in full operation. The crew will be fully integrated and composed of members from the four partners. Day-to-day operations will be centrally planned and coordinated through the Space Station Control Center and Payload Operations Integration Center, but execution of such activities will be initiated and controlled from remote partner payload operation centers as well as from on-board the Manned Base.

FIGURE 4



Figures 1 through 4 and copy for Student Supplement 2 reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

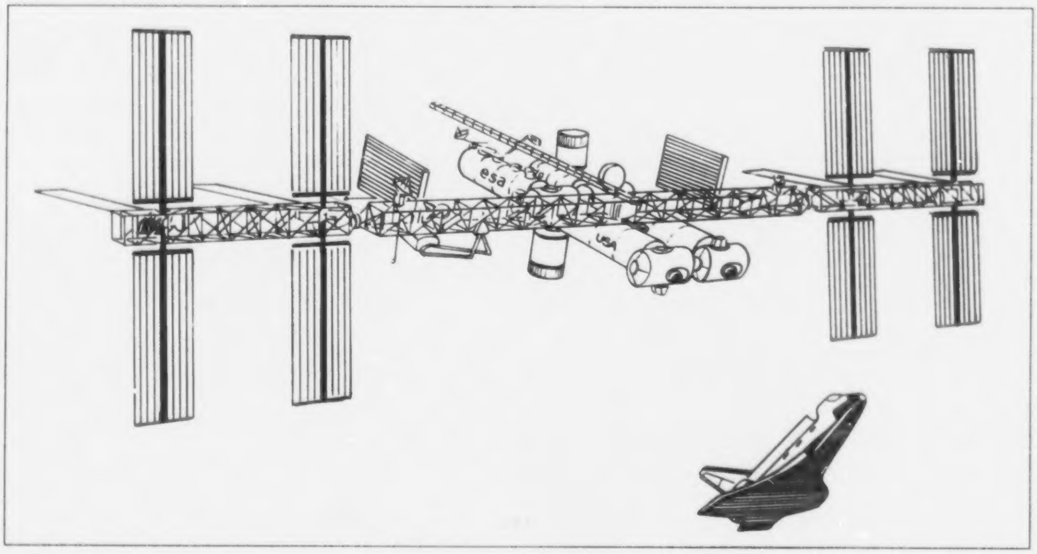
SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

STUDENT SUPPLEMENT 3—FUTURISTIC PERSPECTIVE

Background

Evolutionary planning for the long-term use of Space Station Freedom has been part of the program since the beginning planning stages—Phase A. At the very start, NASA's administrator called for the design of a "station we can buy by the yard," suggesting add-ons, developments, and enhancements. The Space Station Task Force included a "Year 2000" concept that showed growth of the preliminary design, and Phase B contractor studies included system requirements for evolution of the station. Early in the program, two Space Station Evolution Workshops were held in Williamsburg, Virginia, to explore station development. By 1985, it was decided that NASA Headquarters Office of Space Station should manage the evolutionary growth activities. NASA's Office of Exploration requested the Office of Space Station to look at the impacts of accommodating exploration missions. By 1987 the National Research Council Committee on Space Station endorsed the baseline configuration (see Figure 1) and urged NASA to continue to study "alternative evolutionary paths." A Presidential Directive on National Space Policy, issued on February 11, 1988, clearly states that Space Station Freedom "will allow evolution in keeping with the needs of station users and the long-term goals of the U.S."

FIGURE 1



STUDENT SUPPLEMENT 3

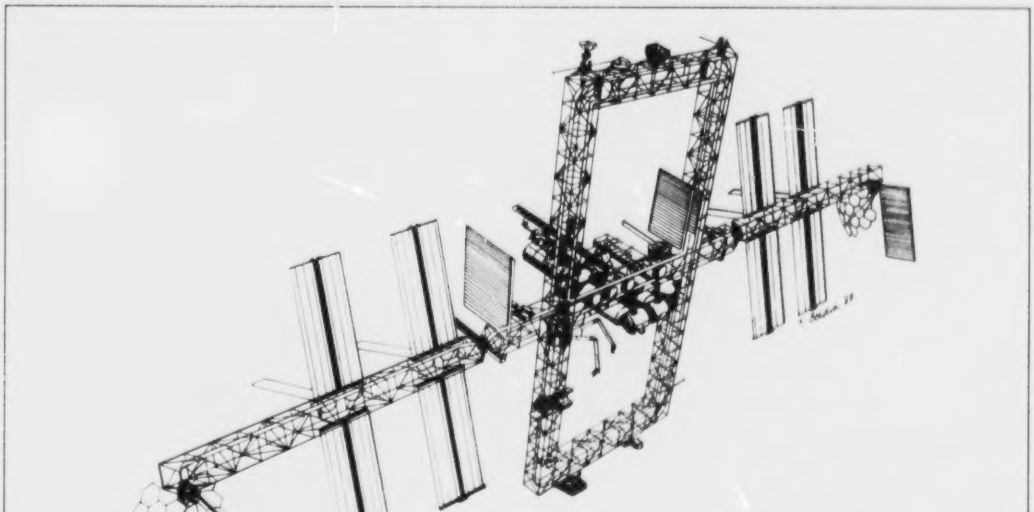
Hooks and scars

From an engineering standpoint, these evolutionary changes will be accommodated by "hooks and scars." A *hook* is aerospace jargon for a design feature for the addition or update of computer software at some future time. Similarly, a *scar* is a jargon for a design feature to add or update hardware at some future time.

Future configuration

Although no decision has been made this far in advance, Space Station Freedom is being considered for enhancement sometime after the 20th assembly flight, planned for early 1998. The long transverse boom will be enhanced by two vertical keels about 105 meters long, and two 45-meter horizontal trusses at top and bottom. See Figure 2. This *dual-keel* configuration will add greater stability to the manned base, provide for many additional attached payloads, and will offer a wide field of view for scientific instruments. Also included is a solar dynamic electric power system with an additional 50 kW. The Mobile Servicing Center (MSC) will be enhanced to handle heavier payloads.

FIGURE 2



STUDENT SUPPLEMENT 3

Lunar and Mars mission support

NASA scientists and technicians are developing scenarios on how Space Station Freedom can support other explorations. The dual-keel configuration lends itself naturally to the function of a transportation node where spacecraft can be assembled, fueled, and checked out for manned missions to the Moon or Mars. Subsequently, such a spacecraft could be berthed, refueled, and repaired at the station upon its return. Space Station Freedom could conduct much-needed research in bioregenerative life-support systems and artificial intelligence. The station could define the limits of human endurance for long-duration manned spaceflights in a weightless and hostile environment. The dual keel further lends itself to experimentation and as a quarantine facility before lunar and Martian samples are returned to Earth. Consequently, as space policy shifts, Congressional intent emerges, user demands change, and humans find new projects for outer space exploration, Space Station Freedom is presently designed for evolution to meet these and yet-unheard-of uses for a 30-year, multipurpose facility in low Earth orbit.

Figures 1 and 2 and copy for Student Supplement 3 reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

STUDENT SUPPLEMENT 4—MANAGEMENT

The Space Station Freedom program uses a three-tiered management structure. The three levels are as follows:

- Level 1, The Office of the Associate Administrator for the Office of Space Station (OSS) at NASA Headquarters in Washington, D.C.
- Level 2, the Space Station Program Office in nearby Reston, Virginia
- Level 3, the four NASA field center project offices.

This structure is shown in Table 1 on the next page.

Level 1: Policy and overall program direction

The Associate Administrator for the Office of Space Station at NASA Headquarters, Level 1, is responsible for the overall management and strategic planning of the program. Principal management responsibilities include

- Policy direction
- Budget formulation
- External affairs
- Space Station Freedom evolution.

The Associate Administrator establishes and controls Level-1 technical and management requirements, milestones, and budget allocations and forecasts. Coordination of external affairs with both legislative and executive branches, user communities, and international partners, as well as internal units of NASA Headquarters that support the program, also falls under the jurisdiction of the Level 1 Office of the Association Administrator.

There are six divisions of Level 1:

- Information systems
- Resources and administration
- Policy
- Operations
- Utilization
- Strategic plans and programs.

STUDENT SUPPLEMENT 4

TABLE 1

LEVEL 1	←	LEVEL 1 SUPPORT CONTRACTOR (TADCORPS)
Office of Space Station, Washington, D.C.		Washington, D.C.
POLICY AND OVERALL PROGRAM DIRECTION		MANAGEMENT, ADMINISTRATIVE, OFFICE AUTOMATION, DOCUMENTATION, GRAPHICS

LEVEL 2	←	PROGRAM SUPPORT CONTRACTOR
Space Station Program Office, Reston, VA		Reston, Virginia
PROGRAM MANAGEMENT AND TECHNICAL CONTENT		GRUMMAN

LEVEL 3			CONTRACTORS
Various NASA Centers			Multiple Locations
PROJECT MANAGEMENT: ELEMENT DEFINITION AND DEVELOPMENT			DETAILED DESIGN, MANUFACTURING, INTEGRATION AND TEST, PLUS ENGINEERING AND TECHNICAL SERVICES
WORK PACKAGE 1 MARSHALL	• Lab Module • Hab Module • Node Structure • Logistics Carriers • Environmental Control & Life Support Systems • Certain Module Outfitting & Distributed Systems	↔	Boeing
WORK PACKAGE 2 JOHNSON	• Truss Structure and Utility Runs • Propulsion System • Data Management • Thermal Control • Communication & Tracking • Attitude Control • Extra-Vehicular System	↔	McDonnell Douglas
WORK PACKAGE 3 GODDARD	• Polar Platform • Payload Attach Points & Pointing Systems • Flight Telerobotic Servicer	↔	General Electric
WORK PACKAGE 4 LEWIS	• Power Generation • Power Management and Distribution	↔	Rocketdyne

STUDENT SUPPLEMENT 4

Level 2: Program management and technical content

The Space Station Program Office (SSPO), Level 2, is responsible for development of the space station, the operational capability of flight and ground systems, and the control of internal and external interfaces. Principal responsibilities include

- Systems engineering and analysis
- Program planning and resource control for both development and operations phases
- Configuration management
- Integration of elements and payloads into an operating system.

This office is headed by the Director of the Space Station Program, who is responsible for the day-to-day management. The Jet Propulsion Laboratory (JPL) provides an independent program requirements and assessment function, attached to this NASA Program Office.

There are four offices and five groups in Level 2. The offices include

- Safety/product assurance
- Program support
- Program integration
- Program requirements and assessment.

The groups include

- Program control
- Program information systems services
- Program utilization and operations
- Program systems engineering and integration
- International programs.

In addition, there are two supporting offices from other NASA organizations: the accounting office and procurement office.

Level 3: Project management: element definition and development

Level 3 consists of four Work Package Centers and their contractors, which are responsible for

- Design, development, testing, and evaluation (DDT&E)
- Operation of hardware and software systems
- Element, evolution, and engineering support.

STUDENT SUPPLEMENT 4

A Space Station Project Office is located at each of these Work Package Centers. The project managers of these offices report to the Director of the Space Station Program.

A Space Station Management Council assists the Associate Administrator in overseeing the program and advises on management, programmatic, and institutional matters. This management council is composed of the Associate Administrator for Space Station and the Deputy; the Director of the Space Station Freedom Program and the Deputy; and the Center Directors of the following NASA Centers:

- Marshall Space Center
- Goddard Space Flight Center
- Lewis Research Center
- Kennedy Space Center
- Langley Research Center
- Jet Propulsion Laboratory.

Other advisory boards, groups, and committees are appointed as necessary and as the program situation dictates.

Work Package 1

The Marshall Space Flight Center (MSFC) in Huntsville, Alabama, and its prime contractor, Boeing Aerospace will design and manufacture

- The astronaut's living quarters—the Habitation Module
- The U.S. Laboratory Module
- The logistics elements
- The resource-node structures connecting the modules
- The Environmental Control and Life Support System
- The Thermal Control and audio-video systems located within the pressurized modules.

It also is responsible for the technical direction of the Work Package 2 contractor for the design and development of the engine elements of the propulsion system. In addition, MSFC is responsible for operations capability development associated with Freedom Station payload operations and planning.

Work Package 2

The Johnson Space Center (JSC) in Houston, Texas, and its prime contractor, McDonnell Douglas Astronautics Company, will manufacture

- The integrated truss assembly
- The propulsion assembly
- The mobile transporter system

STUDENT SUPPLEMENT 4

- The outfitting of the resource node structures provided by Work Package 1
- The EVA system
- The external thermal control system
- The attachment systems for the Space Shuttle and experiments packages
- The guidance, navigation, and control system
- The communications and tracking system
- The data-management system
- The airlocks.

It is also responsible for the technical direction of the Work Package 1 contractor for the design and development of all manned systems. In addition JSC is responsible for flight crews, crew training, and crew emergency return definition, and for operation capability development associated with operations planning.

Work Package 3

The Goddard Space Flight Center in Greenbelt, Maryland, and its prime contractor, the Astro-Space Division of General Electric Company, will manufacture

- Servicing facility
- Flight telerobotic servicer
- Accommodations for attached payloads
- U.S. unmanned free-flyer platforms.

Work Package 4

The Lewis Research Center in Cleveland, Ohio, and its prime contractor, the Rocketdyne Division of Rockwell International, will manufacturer the Electrical Power Systems.

The above Work Package Centers will be supported by other NASA centers in fulfilling their responsibilities. For example, the Ames Research Center will provide supporting research and technology to Work Package 2 in the area of human factors and the EVA system.

Student Supplement 4 reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

ASSIGNMENT SHEET 1—INVESTIGATE SCIENTIFIC USES OF SPACE STATION FREEDOM

Name ______________________________ Score ______________

Introduction

Space Station Freedom will fulfill a long-held dream, a permanent facility in space. No longer will we simply visit space, but we will live and work there around the clock, 365 days a year, well into the 21st century.

The space station will be a versatile system serving a variety of functions, which you reviewed in Objective 4 of the information sheet. This multipurpose system will meet a wide range of NASA mission requirements as well as those of other federal agencies; private scientific, commercial, and technological organizations; and foreign governments. And, as its capabilities increase, the space station's utility will increase and there will be a broader range of scientific endeavors and new spinoffs of space research and development.

Directions

Investigate the scientific uses of Space Station Freedom in one of the following areas: earth resources, astronomical research, the life sciences, or materials processing. Then, on the blanks below, write a report discussing your findings.

ASSIGNMENT SHEET 1

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

ASSIGNMENT SHEET 2—PLAN PRODUCTIVE AND MANAGERIAL PROCESSES FOR CONSTRUCTING A MODEL OF SPACE STATION FREEDOM

Name ______________________________ Score ______________

Introduction

The Space Station Freedom program plan integrates a wide variety of subsystem engineering, technology development, cost analyses and budgetary projections, international planning, and managerial experience into a coherent whole. Student Supplements 2, 3, and 4 describe some the analysis and planning NASA has conducted in relation to this project. The extensive planning conducted has given NASA a good understanding of the productive and managerial issues involved, and as a result of this increased understanding, adjustments were made in the program before construction began. By making adjustments during the planning stages, NASA minimized the likelihood of having to make changes during construction, when changes could be extremely unsettling and very costly.

In Lab Activity Sheet 2 you will construct a complete model of the major structural elements of Space Station Freedom. Although this construction project will be on a smaller scale than the actual construction of Space Station Freedom, planning will play just as important a role in the successful completion of the project. The purpose of this assignment sheet is to guide you through that planning process.

Exercise

Plan productive and managerial processes

Directions

Your instructor will divide your class into three groups: Level 1—Policy and Overall Program Direction, Level 2—Program Management and Technical Content, and Level 3—Project Management. These groups will work together to plan and then construct the space-station model.

Locate Student Supplements 2, 3, and 4. Then complete each of the following steps.

Write a checkmark in the blank before each step as you complete it.

______1. Read Student Supplements 2, 3, and 4 to learn more about the productive and managerial processes NASA plans for construction of Space Station Freedom.

ASSIGNMENT SHEET 2

_____2. Using NASA's management structure shown in Table 1 in Student Supplement 4 and the information discussed in the supplement as a guide, complete a management structure table for the members of your classroom to use in planning the construction of the model space station.

_____3. Using NASA's assembly sequence discussed in Student Supplement 2 as a guide, complete an assembly-sequence plan for the members of your classroom to use in construction of the model space station.

_____4. Attach your management structure table and assembly-sequence plan to this assignment sheet and turn the projects in to your instructor for evaluation.

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

ANSWERS TO ASSIGNMENT SHEETS

Assignment Sheet 1	Evaluated to the satisfaction of the instructor
Assignment Sheet 2	Evaluated to the satisfaction of the instructor

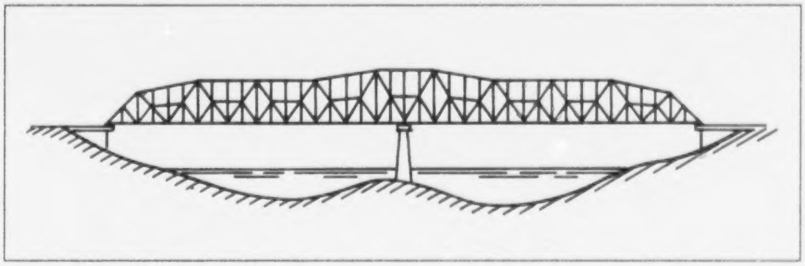
SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT [illegible]

LAB ACTIVITY SHEET 1—CONSTRUCT A MODEL INTEGRATED TRUSS ASSEMBLY

Introduction

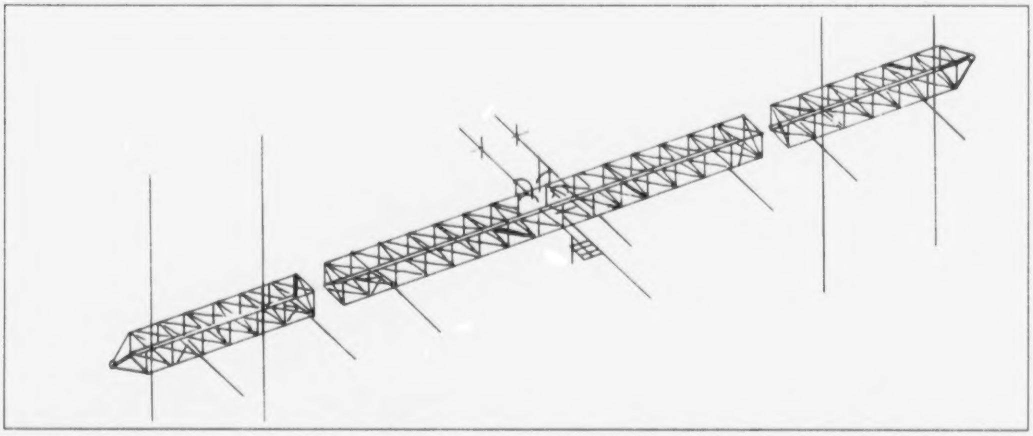
A *truss* is an assembly of members (beams, bars, rods) typically arranged in a triangle or a combination of triangles to form a rigid framework for supporting a load over a wide area. Trusses are often used on Earth in the structural designs of bridges. See Figure 1. Space Station Freedom will use a similar truss design for its main structural framework, called the *integrated truss assembly*. See Figure 2.

FIGURE 1



The integrated truss assembly for Space Station Freedom will consist of a framework of tubular beams forming a transverse boom, which, including solar arrays at each end, will measure 155 meters (508 feet). The 360-foot center of the boom will consist of a sequence of 5-meter (16.4-foot) cubic bays. See Figure 2.

FIGURE 2



Reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

LAB ACTIVITY SHEET 1

Each bay cube will be formed by beams connected at attachment points called *nodes*. See Figure 3-a and -b. There will be a node at each corner of each cube, and adjacent bays will share four common nodes. Diagonal beams within each bay will form the triangles that create the traditional truss design. See Figure 4.

FIGURE 3

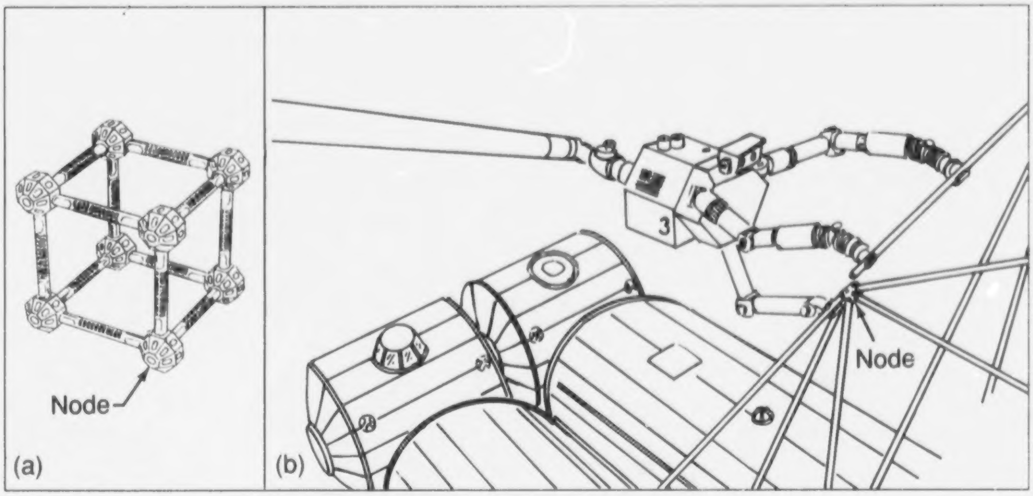
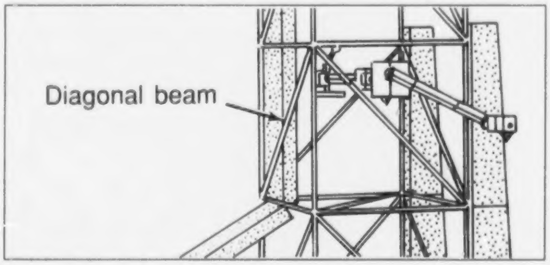


FIGURE 4



Principle of truss design

One of the basic principles of truss design is that **the strength of a truss is based on the rigidity of its triangles**. In this lab activity sheet, not only will you build a model of the integrated truss assembly to be used on Space Station Freedom, you will also explore this principle of truss design.

Figure 3-b and Figure 4 reprinted with permission of the National Aeronautics and Space Administration from *Space Station Freedom Media Handbook*, published by the Office of Space Station, NASA Headquarters, Washington, D.C., April, 1989.

LAB ACTIVITY SHEET 1

Equipment and Materials

- The following components from the Ramagon Very Big Builder set

  —37 nodes
  —62 short beams
  —41 long beams

- Student Supplement 1, "Lab Activity 1 Worksheet"
- Pen or pencil

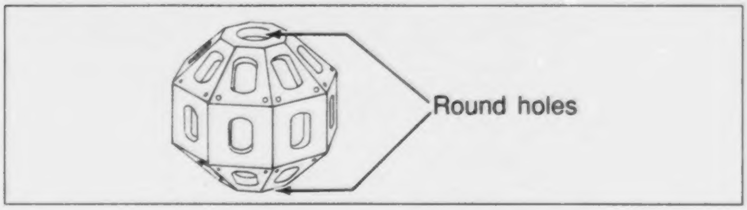
Procedure A **Construct a 7-bay structure and an alpha gimbal**

1. Practice assembling the Ramagon pieces

   a. Locate round holes on top and bottom faces of nodes (Figure 5)

   (NOTE: When you start building, you will need to make sure that the round holes in the nodes face in the same direction.)

FIGURE 5

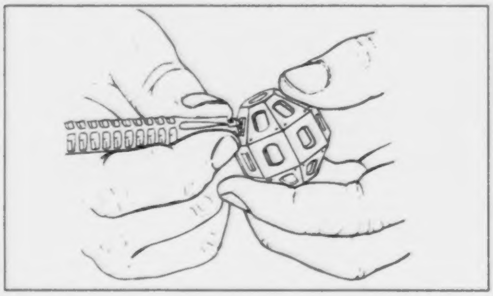


   b. Squeeze end of a beam together and insert beam end into a hole in a node (Figure 6)

   (NOTE: Do **not** force the beam end into the node.)

   c. Squeeze end of beam again and remove beam from node

FIGURE 6



LAB ACTIVITY SHEET 1

2. Construct a square

   a. Locate four nodes and four short beams

   b. Place one node on work surface and orient it so that round holes are on top and bottom; locate vertical faces of node (Figure 7-a)

   c. Insert end of one short beam into a hole on a vertical face of node; insert second short beam on vertical face of node at a 90-degree angle to first beam (Figure 7-b)

   d. Orient second node as in step b and attach node at a 90-degree angle to first beam inserted in step c (Figure 7-c)

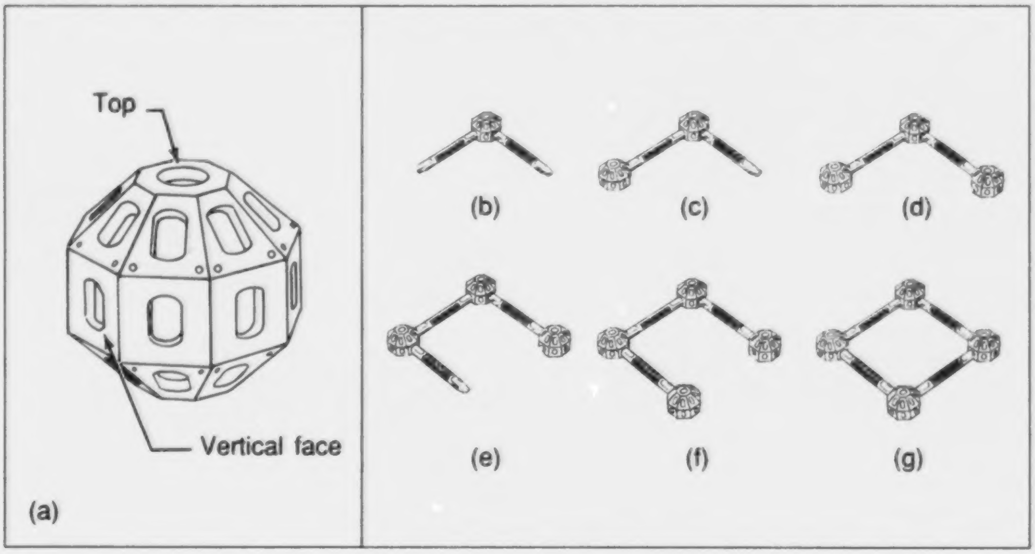
   e. Orient third node as in step b and attach node at a 90-degree angle to second beam inserted in step c (Figure 7-d)

   f. Insert end of one short beam into a hole on vertical face of first node attached in step d (Figure 7-e)

   g. Attach fourth node at a 90-degree angle to short beam inserted in step f (Figure 7-f)

   h. Insert remaining short beam between vertical faces of remaining unconnected nodes to form square (Figure 7-g)

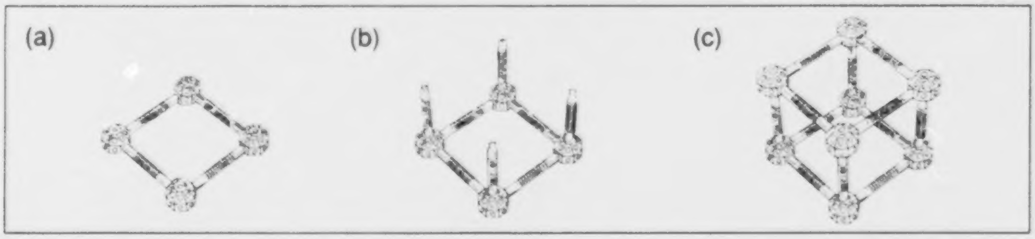
FIGURE 7



LAB ACTIVITY SHEET 1

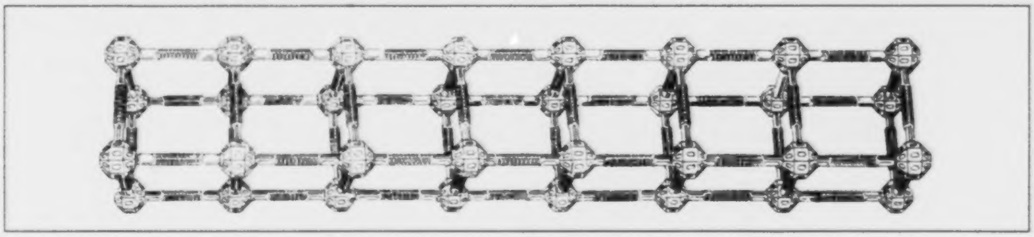
3. Repeat steps 2-a through -h until you have formed 8 squares
4. Construct a cube
    a. Select one square and place it on work surface so that round holes in nodes are on top and bottom (Figure 8-a)
    b. Insert a short beam into each of the top holes (Figure 8-b)
    c. Select another square and place it on short beams inserted in step b to form cube (Figure 8-c)

FIGURE 8



5. Repeat steps 4-a through -c until you have constructed a 7-bay structure (Figure 9)

FIGURE 9



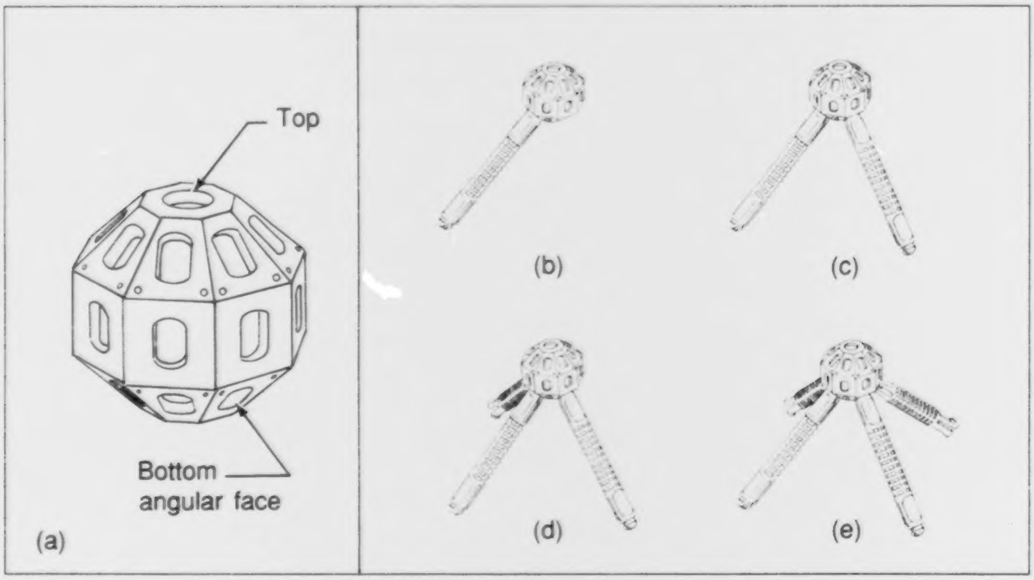
6. Construct alpha gimbal
    a. Locate one node and four short beams
    b. Place node on work surface and orient it so that round holes are on top and bottom; locate bottom angular faces of node (Figure 10-a)
    c. Insert one short beam into a hole on a bottom angular face of node (Figure 10-b)
    d. Skip one hole on node and insert second short beam on a bottom angular face of node (Figure 10-c)

LAB ACTIVITY SHEET 1

e. Skip one hole on node and insert third short beam on a bottom angular face of node (Figure 10-d)

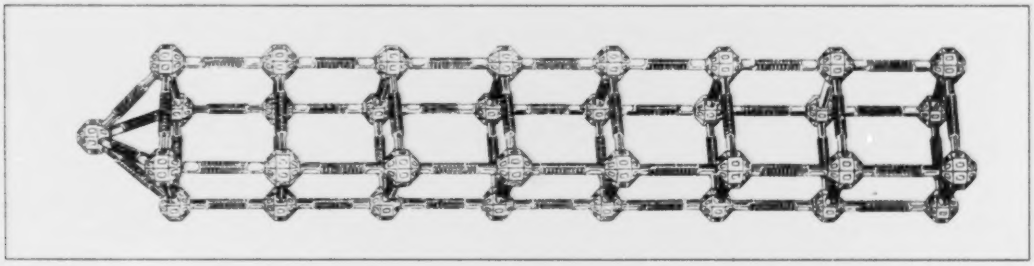
f. Skip one hole on node and insert fourth short beam on a bottom angular face of node to complete alpha gimbal (Figure 10-e)

FIGURE 10



7. Insert alpha gimbal onto the four nodes on one end of 7-bay structure (Figure 11)

FIGURE 11



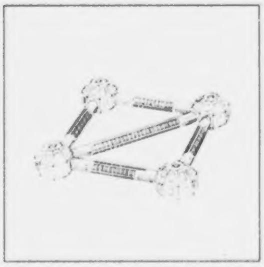
8. Test structure and answer questions as directed on Student Supplement 1

LAB ACTIVITY SHEET 1

Procedure B **Construct a 7-bay truss structure and an alpha gimbal**

1. Disassemble cubes in 7-bay structure but retain 8 squares formed in steps 2 and 3 and alpha gimbal formed in step 6
2. Connect one long beam to form a diagonal between two opposing nodes on each square (Figure 12)

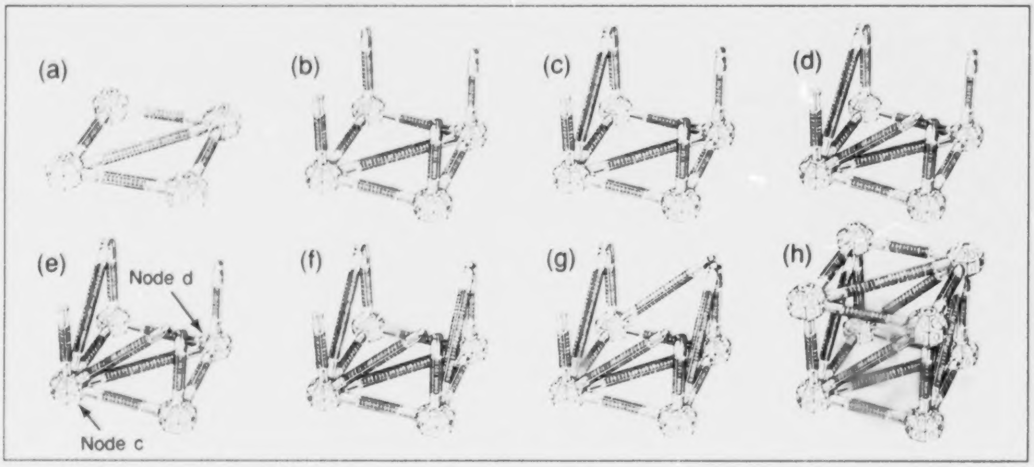
FIGURE 12



3. Construct a cube
    a. Select one square and place it on work surface so that round holes in nodes are on top and bottom (Figure 13-a)
    b. Insert a short beam into each of the top holes (Figure 13-b)
    c. Select one node and insert one long beam into a hole on a bottom angular face of node so that beam extends upward to opposite corner to form triangle (Figure 13-c)
    d. Insert second long beam into a hole on bottom angular face of node selected in step c so that beam extends upward to opposite corner to form second triangle (Figure 13-d)
    e. Locate two nodes at the bottom of each triangle formed in steps c and d (Figure 13-e)
    f. Select one node located in step e and insert third long beam into a hole on bottom angular face of node so that beam extends upward to opposite corner to form third triangle (Figure 13-f)
    g. Select second node located in step e and insert fourth long beam into a hole on bottom angular face of node so that beam extends upward to opposite corner to form fourth triangle (Figure 13-g)
    h. Select another square and insert it on beams to form cube (Figure 13-h)

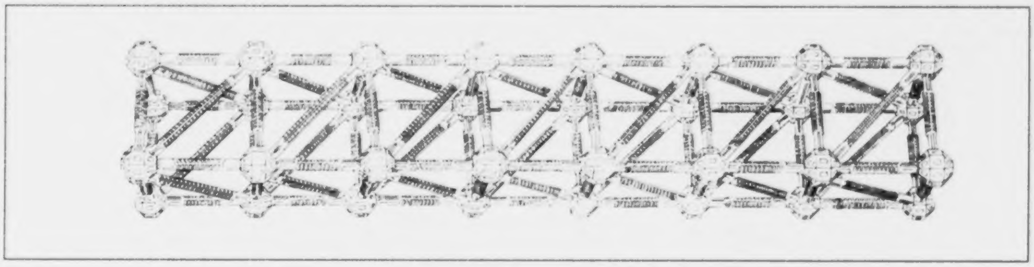
LAB ACTIVITY SHEET 1

FIGURE 13



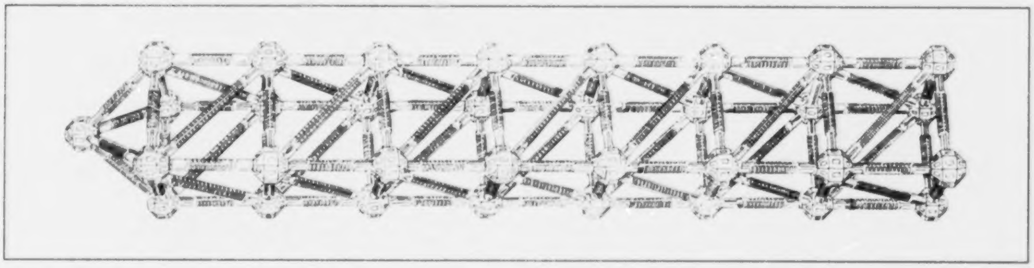
4. Repeat steps 3-a through -h until you have constructed a 7-bay truss structure (Figure 14)

FIGURE 14



5. Insert alpha gimbal onto the four nodes on one end of the 7-bay truss structure (Figure 15)

FIGURE 15



LAB ACTIVITY SHEET 1

6. Test structure and answer questions as directed on Student Supplement 1
7. Turn in Student Supplement 1 to your instructor for evaluation
8. Clean work surface, store 7-bay truss structure properly, and put away other equipment and materials

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

LAB ACTIVITY SHEET 2—CONSTRUCT A COMPLETE MODEL OF THE MAJOR STRUCTURAL ELEMENTS OF SPACE STATION FREEDOM

Introduction

Space Station Freedom will consist of the following major structural elements:

- Integrated truss assembly
- The United States Habitation Module
- The United States Laboratory Module
- The ESA's Columbus Laboratory Module
- The Japanese Experiment Module
- Logistics elements
- Resource nodes
- Photovoltaic power arrays
- Thermal radiators
- Mobile Servicing Center
- The Space Shuttle

You reviewed the definitions and drawings of each of these major elements in Objective 5 of the information sheet. You have learned to construct a model integrated truss assembly in Lab Activity Sheet 1, you have reviewed the uses of a space station in Assignment Sheet 1, and as a member of one of the three classroom groups, you made plans for constructing a model of a space station in Assignment Sheet 2. As a group, you should now have at your disposal all the information you need to build a complete model of Space Station Freedom.

Procedure

Build a model of Space Station Freedom that includes the major components listed above.

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

WRITTEN TEST

Name ______________________________ Score ______________

1. Match terms associated with space-station construction to their correct definitions. Write the correct numbers on the blanks provided.

______	a.	Production of a structure on site	1. Construction
______	b.	Something made up of a number of parts that are held or put together in a particular way	2. Structure

2. Match components of the construction system model to their correct definitions. Write the correct numbers on the blanks provided.

______	a.	Customer/user response, profit and loss, and quality control	1. Inputs
			2. Processes/productive
______	b.	Planning, organizing, directing, and controlling	3. Processes/managerial
______	c.	Structure	4. Outputs
______	d.	People, knowledge, materials, energy, capital, and money	5. Feedback
______	e.	Preparing to build, designing the project, building the structure, installing systems, finishing the structure, completing the site and closing the contracts, and servicing the project	

3. Define the term *construction technology*. Write your definition on the blanks provided.

Construction technology ____

____

____

____

____

____

____

WRITTEN TEST

4. List three of the seven objectives of space-station design. Write your answers on the blanks provided.

a. ______________________________

b. ______________________________

c. ______________________________

5. Match major space-station structural elements to their correct definitions. Write the correct numbers on the blanks provided.

______a. Framework and attachment point for other space-station elements

______b. Replaceable cargo canisters attached to the station truss or to a module and designed to fit into the cargo bay of the Space Shuttle to transport equipment, supplies, and fluids to the station and to return experiment results, equipment, and waste products back to Earth

______c. Rail-mounted center containing a robotic arm that will be moved along the truss to perform assembly and maintenance duties

______d. Vehicle to transport the materials for the initial assembly and checkout of the space station and later to provide continued roundtrip transportation for crews and supplies between the Earth and the space station

______e. Pressurized cylinders to provide astronauts with living quarters and research centers for conducting materials research, life-sciences research, and other space-science investigations

______f. Pressurized cylinders designed to serve as command and control centers and as passageways to and from modules

______g. Panels designed to interface with the environmental-control and life-support systems to remove excess heat from the atmosphere of the pressurized modules and nodes

______h. Panels of solar cells designed to provide the electrical power needed for space-station operations

1. Integrated truss assembly
2. Laboratory and habitation modules
3. Logistics elements
4. Resource nodes
5. Photovoltaic power arrays
6. Thermal radiators
7. Mobile Servicing Center
8. Space Shuttle

WRITTEN TEST

6. Discuss techniques to be used in space-station construction. Write your answers on the blanks provided.

SPACE-STATION CONSTRUCTION TECHNIQUES
UNIT IV

WRITTEN TEST ANSWERS

1. a. 1
   b. 2

2. a. 5
   b. 3
   c. 4
   d. 1
   e. 2

3. Effective use of materials, labor, equipment, methods, and management resources to produce a structure on site

4. Answer should include any three of the following

   a. Laboratory
   b. Permanent observatory
   c. Servicing/repair facility
   d. Assembly facility
   e. Manufacturing facility
   f. Storage depot
   g. Staging base

5. a. 1
   b. 3
   c. 7
   d. 8
   e. 2
   f. 4
   g. 6
   h. 5

6. Discussion should include the following

   a. On-earth construction—Resource nodes, laboratory and habitation modules, logistic elements, solar arrays, and thermal radiators will be constructed on Earth and transported into space by the Space Shuttle. They will be finished products before they are transported and will need only to be attached to the integrated truss assembly once in space

   b. In-space construction—The beams for the integrated truss assembly will be manufactured on Earth, transported into space by the Space Shuttle, and then the integrated truss assembly will be constructed in space

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

UNIT OBJECTIVE

After completing this unit, the student should be able to define the parts of solid- and liquid-propellant rockets, identify the major units of the Space Shuttle's propulsion system and their major components, compare the propulsion systems of solid- and liquid-propellant rockets, and complete a rocket launch. The student will demonstrate these competencies by completing the assignment sheet, lab activity sheets, and written test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. Match terms associated with propulsion systems to their correct definitions.
2. State definitions of types of rocket propulsion systems.
3. Match parts of a solid-propellant rocket engine to their correct definitions.
4. Match parts of a liquid-propellant rocket engine to their correct definitions.
5. Discuss the principle of rocket propulsion.
6. Label the major units of the Space Shuttle's propulsion system.
7. Identify the major components of the Space Shuttle's main engines.
8. Label the major components of the Space Shuttle's external tank.
9. Identify the major components of the Space Shuttle's solid-rocket boosters.
10. Compare the propulsion systems of solid- and liquid-propellant rockets. (Assignment Sheet 1)
11. Simulate a multi-stage rocket launch. (Lab Activity Sheet 1)
12. Construct a solid-propellant model rocket. (Lab Activity Sheet 2)

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

SUGGESTED ACTIVITIES

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review teaching suggestions given in the "Delivery and Application" section and plan classroom activities.

  Plan presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain materials to supplement instruction of this unit. See ordering information in the "Suggested Resources" section.

- Prepare classroom and lab. Put up posters, charts, and signs and display articles related to the objectives of this unit.

- Please notice that in designing this unit, we have tried to comply with the policies established by the National Association of Rocketry and several other national educational organizations who warn that such launchings should not be a part of the science curriculum—unless the launchings are as rigidly controlled and expertly supervised as are the experiments by rocket scientists and engineers. This means that under no circumstances should a student build a rocket, mix rocket fuel, load a rocket, or attempt to launch it without supervision by an adult rocket expert.

  The Office of Education also offers the following specific safety rules to guide educators in designing their curriculum:

  1. Encourage students to learn about the broad field of space exploration instead of rocketry alone.
  2. Emphasize the need for school science teachers to keep up to date on scientific developments in this new field.
  3. Remember that teachers should not supervise experiments with rocket fuels or launchings unless they have had military or industrial experience in rocketry or unless such a person is also present.
  4. Become familiar with local laws concerning rocket launchings and the use of dangerous fuels, chemicals, and combustibles.

SUGGESTED ACTIVITIES

5. Rockets can be a hazard to planes in flight. Persons in charge of rocket launchings should seek the advice of the nearest FAA Safety Inspector as well as local fire and police officials. Rockets that do not exceed an altitude of 500 feet do not need FAA clearance. However, they must not be launched within 5 miles of an airport or an FAA "airway." Amateur rocketeers should be warned they are fully responsible for any damage to persons or property resulting from their activity.

6. Inform parents of their responsibilities if their children are interested in rocketry:

   - Know where your child is working; what he or she is attempting; and that a qualified supervisor is present.

   - Remember that even common chemicals can be dangerous if misused.

Teacher Supplements 2, 3, and 4 in this unit have been designed as resources for instructors to use in the event they want to become qualified rocket supervisors and then include actual rocket launchings as a part of the curriculum. Teacher Supplement 2 provides the teacher with the names and addresses of various organizations that can provide him or her with the information necessary for establishing a safe rocket curriculum. Teacher Supplement 3 lists firms that meet the standards of the National Association of Rocketry as sources for rocket kits that will be ordered for students to complete Lab Activity Sheet 2.

Student Supplement 4 should be given to students and their parents as a part of their safety education before any rocket launchings are attempted.

Delivery and Application

Unit Introduction

- Provide students with objective sheet. Discuss unit and specific objectives.

- Explain to students that they will be learning some basic principles of rocket propulsion and how these basic principles are reflected in the designs of the three main units of the Space-Shuttle's propulsion system: the Shuttle's main engines, the solid-rocket boosters, and the external tank. Use Teacher Supplement 1, "Propulsion Trivia" to spark student interest and help students visualize the complexities of the designs of these three propulsion units.

SUGGESTED ACTIVITIES

Objective 1 Match terms associated with propulsion systems to their correct definitions.

Objective 2 State definitions of types of rocket propulsion systems.

- Explain to students that it is important that they carefully distinguish between the terms *fuel* and *propellant* and not use them interchangeably. A rocket propellant is a mixture composed of both a fuel and an oxidizer—both agents must be present before a propellant can burn properly when ignited and therefore propel a rocket.

- There are then two major types of propellants: liquid and solid. Liquid propellants are either liquid or gas fuels that are mixed with an oxidizer and solid propellants are solid fuels compounded with an oxidizer. Have students review the listings of fuels and oxidizers given in Student Supplement 3 to provide students with examples of fuels and propellants.

Objective 3 Match parts of a solid-propellant rocket engine to their correct definitions.

Objective 4 Match parts of a liquid-propellant rocket engine to their correct definitions.

Objective 5 Discuss the principle of rocket propulsion.

- Treat these three objectives as a unit discussing the basic principles of rocket propulsion.

  Use the simple illustrations in Objectives 3 and 4 to help students visualize the essential differences and similarities between the two types of rocket propulsion systems—solid and liquid. Be sure to stress the purpose of the nozzle in both systems and to discuss the two main parts of the nozzle—the bell and the throat.

  Use Objective 5 as a simple explanation of how both liquid- and solid-rocket propulsion systems function. For more advanced students, supplement this objective with the discussion of Newton's laws of motion in Teacher Supplement 4, "Rocket Principles."

Objective 6 Label the major units of the Space Shuttle's propulsion system.

Objective 7 Identify the major components of the Space Shuttle's main engines.

SUGGESTED ACTIVITIES

Objective 8 Label the major components of the Space Shuttle's external tank.

Objective 9 Label the major components of the Space Shuttle's solid-rocket boosters.

- Treat these four objectives as a unit that describes the major units of the Space Shuttle's propulsion system—the main engines, external tank, and solid-rocket boosters—and their components. Use the Figures 5 through 8 in the information sheet to illustrate your discussion of these components.

- Compare the illustration of the parts of a solid-propellant rocket in Objective 3 to the illustration of the components of the solid-rocket boosters shown in Objective 9.

- Compare the illustration of the parts of a liquid-propellant rocket in Objective 4 to the illustrations of the components of the Space Shuttle's main rocket engines shown in Objective 7 and the components of the external tank shown in Objective 8.

- Point out to students the stages in the multi-stage launch used to launch the Space Shuttle. Discuss the notes on the launch sequence that accompany Objectives 6 through 9. Use Transparencies 1 through 4 to illustrate your discussion.

- Read and discuss with students the introduction to Lab Activity Sheet 1, "Simulate a Multi-Stage Rocket Launch." Have students complete the lab activity.

- Read with students and help them outline the information presented in Student Supplements 1, 2, and 3. Then discuss with students the exercises presented in Assignment Sheet 1, "Compare the Propulsion Systems of Solid- and Liquid-Propellant Rockets." Students will demonstrate higher-order thinking skills by assimilating the information presented in the supplements in order to complete this assignment sheet correctly. Guide them through this difficult, but worthwhile, process.

- Read and discuss with students the introduction to Lab Activity Sheet 2, "Construct a Solid-Propellant Model Rocket." Also explain that students must read and complete Student Supplement 4 before they will be allowed to complete the lab activity.

- Demonstrate the correct procedure for constructing the rocket kit of your choice.

- Have students complete Lab Activity Sheet 2.

SUGGESTED ACTIVITIES

Evaluation

- Give written test.
- Compile written-test, assignment-sheet, and lab-activity-sheet scores.
- Reteach and retest as required.

Suggested Resources

Resources used in developing unit

Print media

- National Aeronautics and Space Administration. *NASA Educational Briefs*, "Liquid-Propellant Rockets," 1982. Washington, D.C. 20546. Government Printing Office number 1982-361-570-414/3257.

  The educational brief, though adapted somewhat, is printed in Student Supplement 1.

- National Aeronautics and Space Administration. *NASA Educational Briefs*, "Solid Propellant Rockets." Washington, D.C. 20546. Government Printing Office number 883-556.

  The educational brief, though adapted somewhat, is printed in Student Supplement 2.

- National Aeronautics and Space Administration. *NASA FactSheet: Propulsion Trivia*, MSFC-Form 2914-12 (Rev. March 1990). George C. Marshall Space Flight Center, Marshall Space Flight Center, Alabama 35812.

  The fact sheet is printed in Teacher Supplement 1. To order student copies of the supplement, contact the Marshall Space Flight Center at the above address.

- Vogt, Gregory. *Rockets*. National Aeronautics and Space Administration, Aerospace Education Services, n.d. (preliminary draft).

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

TEACHER SUPPLEMENT 1—PROPULSION TRIVIA

- The Space-Shuttle main engine operates at greater temperature extremes than any mechanical system in common use today. The fuel, liquified hydrogen at -423 degrees F, is the second coldest liquid on earth. When it and the liquid oxygen are combusted, the temperature in the main combustion chamber is 6000 degrees F, higher than the boiling point of iron.

- The energy released by the three Space-Shuttle main engines at full power level, in units of watts, is equivalent to the output of 23 Hoover Dams.

- The Space-Shuttle main-engine fuel turbopump weighs approximately the same as the V-8 engine of a modern automobile, but develops 310 times the brake horsepower and develops as much torque as 18 V-8 automobile engines.

- One Space-Shuttle main engine generates sufficient thrust to maintain the flight of two and one-half 747s.

- The combined volume of the external tank's liquid-hydrogen and liquid-oxygen tanks is 73,600 cubic feet. That is equal to the volume of nearly six 1600-square-foot houses.

- If all the weld joints in the external tank were laid out in a straight line, they would stretch more than a half mile.

- The external tank is covered with a thermal-protection system (insulation) that if spread on the ground would cover nearly one-half acre.

- The two solid-rocket boosters generate a combined thrust of 5.3 million pounds, equivalent to 44 million horsepower or 400,000 subcompact cars.

- At liftoff, the two solid-rocket boosters consume 11,000 pounds of fuel per second. That's two million times the rate at which fuel is burned by the average family car.

- At 149 feet, 1.6 inches tall, the solid-rocket booster is only two feet shorter than the Statue of Liberty. But, each 700-ton loaded solid-rocket booster weighs more than three times as much as the famous statue.

Reprinted with permission of the National Aeronautics and Space Administration, from *NASA FactSheet: Propulsion Trivia*, George C. Marshall Space Flight Center, Alabama, March 1980.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

TEACHER SUPPLEMENT 2—SAFETY-INFORMATION SOURCES

Student rocketry programs will be much more rewarding for both students and the instructor or rocket-society supervisor if groups begin their efforts with a study of the basic reasons for space exploration, a review of what has been learned regarding man's space frontier, a course in the fundamental principles of rocket propulsion, and—if their instructor/rocket-society supervisor determines that the group should work with actual rockets—a course in basic rocket-safety information.

The organizations listed in this supplement have a great variety of information available for the instructor/rocket-society supervisor on the level he or she wishes to establish for his or her students. To help the instructor/supervisor determine the type of assistance available, the following list of organizations has been provided. The organizations are listed in alphabetical order, and the following code has been utilized to indicate the type of information available from each organization.

GAI—General aerospace information
SI—Safety information
ISSP—Information for supervised student programs

This listing is not intended to be all-inclusive.

- Academy of Model Aeronautics
  1810 Samuel Morse Drive
  Reston, Virginia 22090

  ISSP

  The Academy, a division of the National Aeronautical Association, has brought rule and order to the hobby of model aeronautics. One of their publications is the *Official Model Aircraft Regulations*, a section of which is devoted to rocket-powered free-flight models, which use Jetex for propulsion. The AMA sanctions local contests and conducts the annual National Model Airplane Championships. The AMA monthly newsletter, *Model Aviation*, became part of the *American Modeler Magazine*, beginning with the July/August 1966 issue. Members of the AMA receive this combined publication as part of their membership.

- Aerospace Industries Association of America, Inc.
  1725 DeSales Street, NW
  Washington, D.C. 20036

  GAI

  This association of the various aerospace industries in the United States is a good source of information for educators/rocket-society supervisors. In addition to charts and booklets, the AIA publishes a monthly newsletter, *Aerospace*, and an annual *Aerospace Year Book*.

TEACHER SUPPLEMENT 2

- American Chemical Society
  Division of Chemical Education
  1155 16th Street, NW
  Washington, D.C. 20036

SI

The *Journal of Chemical Education* is published by this ACS division. The instructor/rocket-society supervisor should see this current issue each month and check back issues for valuable safety information.

- American Institute of Aeronautics and Astronautics
  Education and Student Affairs Committee
  1290 6th Avenue
  New York, New York 10019

GAI **ISSP**

The AIAA, formed in 1963, is a consolidation of the American Rocket Society and the Institute of Aerospace Sciences, the leading contemporary professional societies in their fields. ARS was founded in 1930 and the IAS in 1932. Student branches are established in colleges and universities throughout the United States. Publications include *Astronautics & Aeronautics*, *AIAA Journal*, *Journal of Spacecraft and Rockets*, *Journal of Aircraft*, *AIAA Bulletin*, *AIAA Student News Reporter*, the *AIAA Student Journal*, and *International Aerospace Abstracts*. The AIAA, through its publications and meetings, is one of the major sources of unclassified information for the aerospace community. Also available is a small pamphlet entitled *An Open Letter to Amateur Rocketeers* by Zimmerman, who expresses well this society's concern about the hazards of rocket experimentation.

- Model Rocket News
  Box 227
  Penrose, Colorado 81240

ISSP

One of the most useful publications for the student interested in constructing model rocket vehicles for use with the various model rocket engines is *Model Rocket News*, a publication of Estes Industries. Vern Estes, the president of this pioneering firm, which developed the first automatic equipment for the manufacture of model rocket engines, edits this excellent publication and usually includes in each issue plans for new model-rocket vehicles as well as other useful information.

- National Aeronautics and Space Administration
  Educational Programs Services Office
  Washington, D.C. 20546

GAI

Publications of NASA's Educational Programs and Services Office are available to educators as well as the public at large. Booklets and pamphlets deal with space,

TEACHER SUPPLEMENT 2

the work of NASA, and scientific programs and projects. *NASA FACTS* is the title of a series of fact sheets suitable for wall display or notebook insertion. Comprehensive bibliographies of space science books, pamphlets, and teaching aids are published for the elementary, secondary, and adult levels.

A current list of publications available may be obtained by writing

Educational Publications
NASA Headquarters
Code XEP
Washington, D.C. 20546.

Single copies of publications are available from the same source. Also, most NASA educational publications are listed for sale by the

Superintendent of Documents
Government Printing Office
Washington, D.C. 20402.

Quantity orders from the Government Printing Office are allowed discounts.

- National Association of Rocketry
  1311 Edgewood Drive
  Altoona, Wisconsin 54720

ISSP

The National Association of Rocketry (NAR) is the largest model rocketry (spacemodeling) organization in the world. The National Association of Rocketry is an affiliate of the National Aeronautic Association (Washington, D.C.), the Federation Aeronautique Internationale (Paris, France), and the Hobby Industries of America (Elmwood Park, New Jersey).

The NAR sponsors national and international model rocketry competition. As a member you can fly your models in competition with rocketeers from all over the world. You can set national and international flight records. You can compete in the annual United States Model Rocket Championships (National Contest and Convention) sponsored by the NAR. You can compete in the bi-annual World Model Rocket Championships sponsored by the FAI.

As a member, you can join any one of 60 NAR-affiliated model rocket clubs. These clubs are scattered throughout the United States. If there is not one in your area, it is easy for you as a member to form your own affiliated club.

Each month, as a member, you receive the *American Spacemodeling* magazine. Complete with full-color, glossy-stock cover, it is filled with rocket plans, model rocket articles by other members just like yourself, plus helpful tips and hints on how to be a better modeler. It gives a monthly listing of model rocket contests, conventions, and sport launches all across the country. It puts you into contact with thousands of model rocketeers all across the United States.

TEACHER SUPPLEMENT 2

Members receive a copy of the *United States Model Rocket Sporting Code*, which outlines in detail the competition rules in forty different kinds of NAR contest events. Members may purchase at low rates—decals, jacket patches, model rocket books, complex scale plans, research and development reports, basic to advanced technical reports, slides, and even posters.

Members also receive product discount coupons with many aeromodeling and model rocket manufacturers. These coupons can save members up to $50 on their annual rocket and hobby supplies.

Members may purchase low-cost model-rocket liability insurance. This insurance covers up to $100,000 in bodily injuries and property damage while flying model rockets in accordance to the NAR/HIA Model Rocket Safety Code. It can be purchased by members or by NAR-affiliated clubs.

The NAR was founded on December 7, 1957, as the Model Missile Association. The present name was adopted in October, 1958. The organization has chapters throughout the United States and performs many of the same functions for model rocketry that the AMA performs for model aircraft. The NAR has organized and sponsored their National Model Rocket Championships, called NARAM, since the first one on July 16 through 19, 1959. Membership in the NAR is open to anybody, regardless of age, and membership dues are based on the age of the applicant. All members signify upon joining that they will obey the strict NAR Safety Code and that they will abide by the NAR rules in model rocket work.

- National Science Teachers Association
  1742 Connecticut Avenue, N.W.
  Washington, D.C. 20009

GAI

The National Science Teachers Association (NSTA), a department of the National Education Association (NEA) and an affiliate of the American Association for the Advancement of Science (AAAS), is developing with NASA on a cooperative basis two series of paperback books: *Vistas of Science*, for secondary-level students, and *Investigating Science with Children*, for elementary-level students. The Future Scientists of America is also sponsored by the NSTA.

- Science Service
  1719 North Street, N.W.
  Washington, D.C. 20036

ISSP GAI

Science Service is the Institution for the Popularization of Science, organized in 1921 as a nonprofit corporation. Its trustees are nominated by the National Academy of Sciences, the National Research Council, the American Association for the Advancement of Science, the E.W. Scripps Estate, and the journalistic profession. Science Service is responsible for the famous science fairs held throughout the United States, the National Science Fair-International, and the Science Talent Search. *Science News Letter*, a nontechnical magazine covering current developments in all the sciences, is perhaps the publication most familiar to students and the general public.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

TEACHER SUPPLEMENT 3—SOURCES FOR ROCKET KITS, PARTS, AND ACCESSORIES

The following firms comply with standards established by the National Association of Rocketry.

- Estes Industries
  1295 H. Street
  Penrose, CO 81240

  Estes Industries is a leader in the model-rocket industry. Estes carries a complete line of model rocket kits, motors, launchers, and educational materials.

- Apogee Components
  11111 Greenbrier Road
  Minnetonka, MN 55343

  Apogee Components is your source for high-technology competition parts. Apogee's components include phenolic body tubes, injection-molded nose cones, and "waferglass" fin stock.

- Spectrum Video Productions
  Box 3698
  Ontario, CA 91761

  Spectrum Video Productions offers a complete line of NASA films in the VHS format. Film topics include Mercury, Gemini, and Apollo missions as well as coverage of many of the Space Shuttle missions.

- U.S. Rockets
  Box 1242
  Claremont, CA 91711

  U.S. Rockets offers kits and parts for the high-power rocket enthusiast.

- Model Aviation Fuels
  R.D. 6 Box 172
  Clarke Summit, PA 18411

  Model Aviation Fuels offers interesting kits to the model-rocket enthusiast. They offer body tubes, nose cones, and fin materials for the D-E-F-G powered models.

- MARS
  2240 9th Street
  National City, CA 92050

  MARS offers specialized tubes for the modeler. Their tubes are bright silver for easy tracking.

TEACHER SUPPLEMENT 3

- Space Frontiers
  Box 6488
  Newport News, VA 23606

  Space Frontiers magazine offers modelers interesting facts on space and rocketry. This magazine is a must for the scale modeler.

- Belleville Wholesale Hobby
  1827 North Charles Street
  Belleville, IL 62211

  Belleville Wholesale Hobby offers the complete line of Estes products to the modeler, at a substantial savings for your local hobby store.

- FSI
  9300 East 68th Street
  Raytown, MO 64133

  Flight Systems, Inc., has long been a leader in D-G powered model rockets. FSI offers a complete line of kits and motors.

- ACME Rockets
  Box 28283 Department AS27
  Tempe, AZ 85285-8283

  ACME rockets is your source for out-of-production model-rocket kits. If you're interested in building the kits of yesterday, then ACME is the place to go.

- East Coast Rockets
  408 Lark Drive
  Mount Laurel, NJ 08054

  East Coast Rockets offers a line of kits for the A-D class model-rocket flyer. ECR also sells a line of parts and accessories.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

TEACHER SUPPLEMENT 4—ROCKET PRINCIPLES

Introduction

The science of rocketry began with the publishing of a book in 1687 by the great English scientist Sir Isaac Newton. His book, entitled *Philosophiae Naturalis Principia Mathematicia*, described physical principles in nature. Today, Newton's work is usually just called the *Principia*.

In the *Principia*, Newton stated three important scientific principles that govern the motion of all objects, whether on earth or in space. Knowing these principles, now called *Newton's laws of motion*, rocketeers have been able to construct the modern giant rockets of today such as the Saturn V and the Space Shuttle. Here now, in simple form, are Newton's laws of motion.

1. Objects at rest will stay at rest or objects in motion will stay in motion in a straight line unless acted upon by an unbalanced force.
2. Force is equal to mass times acceleration.
3. For every action there is always an opposite and equal reaction.

As will be explained shortly, all three laws are really simple statements of how things move. But with them, precise determinations of rocket performance can be made.

Newton's first law

This law of motion is just an obvious statement of fact, but to know what it means, it is necessary to understand the terms *rest*, *motion*, and *unbalanced force*.

Rest and *motion* can be thought of as being opposite to each other. *Rest* is the state of an object when it is not changing position in relation to its surroundings. If you are sitting still in a chair, you can be said to be at rest. The term, however, is relative. Your chair may actually be one of many seats on a speeding airplane. The important thing to remember here is that you are not moving **in relation to your immediate surroundings**. If rest were defined as a total absence of motion, it would not exist in nature. Even if you were sitting in your chair at home, you would still be moving because your chair is actually sitting on the surface of a spinning planet that is orbiting a star, and the star is moving through a rotating galaxy that is, itself, moving through the universe. While sitting "still" you are, in fact, traveling at a speed of hundreds of miles per second.

Motion is also a relative term. All matter in the universe is moving all the time, but in the first law, *motion* means "changing position in relation to surroundings." A ball is at rest if it is sitting on the ground. The ball is in motion if it is rolling because then it is changing its position in relation to its surroundings. When you are sitting on a chair in an airplane, you are at rest, but if you get up and walk down the aisle, you are in motion. A rocket blasting off the launch pad changes from a state of rest to a state of motion.

TEACHER SUPPLEMENT 4

The third term important to understanding this law is *unbalanced force*. If you hold a ball in your hand and keep it still, the ball is at rest. All the time the ball is held there though, it is being acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. The forces acting on the ball are balanced. Let the ball go, or move your hand upward, and the forces become unbalanced. The ball then changes from a state of rest to a state of motion.

In rocket flight, forces become balanced and unbalanced all the time. A rocket on the launch pad is balanced. The surface of the pad pushes the rocket up while gravity tries to pull it down. As the engines are ignited, the thrust from the rocket unbalances the forces, and the rocket travels upward. Later, when the rocket runs out of propellant, it slows down, stops at the highest point of its flight, then falls back to earth.

Objects in space also react to forces. A spacecraft moving through the solar system is in constant motion. The spacecraft will travel in a straight line if the forces on it are in balance. This happens only when the spacecraft is very far from any large gravity source such as the Earth or the other planets and their moons. If the spacecraft comes near a large body in space, its gravity will unbalance the forces and curve the path of the spacecraft. This happens, in particular, when a spacecraft is sent by a rocket on a path that is parallel to the Earth's surface. If the rocket shoots the spacecraft fast enough, the spacecraft will orbit the Earth. As long as an unbalanced force (friction or the firing of a rocket engine in the opposite direction from its movement) does not stop the spacecraft, it will orbit the Earth forever.

Now that the three major terms of this first law have been explained, it is possible to restate this law: **If an object, such as a rocket, is at rest, it takes an unbalanced force to make it move. If the object is already moving, it takes an unbalanced force to stop it or to change its direction or speed.**

Newton's Third Law

For the time being, we will skip the second law and go directly to the third. This law states: **Every action has an equal and opposite reaction.** If you have ever stepped off a small boat that has not been properly tied to a pier, you will know exactly what this law means.

A rocket can lift off from a launch pad only when it expels gas out of its engine. The rocket pushes on the gas, and the gas in turn pushes on the rocket. The whole process is very similar to riding a skateboard. Imagine that a skateboard and rider are in a state of rest (not moving). The rider steps off the skateboard. In the third law, the stepping off is called an *action*. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's motion is called a *reaction*.

With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the weight of the rocket.

TEACHER SUPPLEMENT 4

Newton's Second Law

This law of motion is essentially a statement of a mathematical equation. The three parts of the equation are mass (m), acceleration (a), and force (f). Using letters to symbolize each part, the equation can be written as follows:

$$f = ma.$$

By using simple algebra, we can also write the equation two other ways:

$$a = \frac{f}{m}, \text{ or}$$

$$m = \frac{f}{a}.$$

The first version of the equation is the one most commonly referred to when talking about Newton's second law. It reads: **Force equals mass times acceleration.**

Force in the equation can be thought of as the thrust of the rocket. *Mass* is the amount of rocket propellant being burned and converted into gas that expands and then escapes from the rocket. *Acceleration* is the rate at which the gas escapes. Inside the rocket, the gas does not really move, but as it leaves the engine, it picks up speed.

The second law of motion is especially useful when designing effective rockets. To enable a rocket to climb into low earth orbit or escape the Earth's gravitational pull, it is necessary to achieve velocities, or speeds, in excess of 17,500 miles (28,000 km) per hour. The speed necessary to escape the Earth's gravity—25,000 (40,250 km) per hour—is called *escape velocity*. Attaining escape velocity requires the rocket engine to achieve the greatest action force possible in the shortest time. In other words, the engine must burn a large mass of propellant and push the resulting gas out of the engine as rapidly as possible.

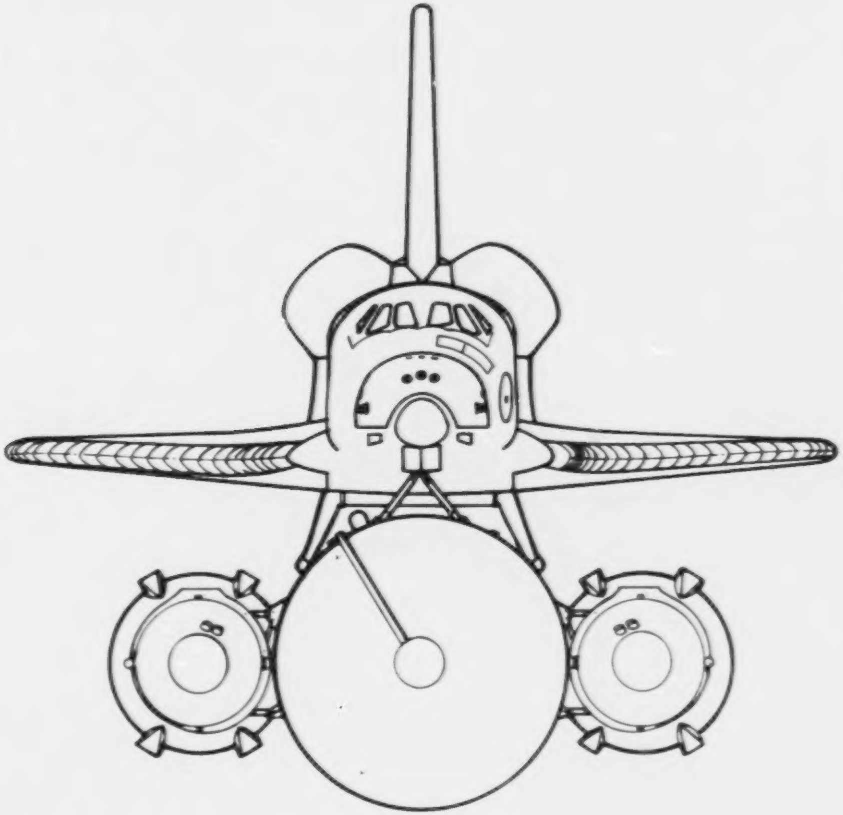
Newton's second law of motion can be restated in the following way: **The greater the mass of rocket propellant burned and the faster the gas produced can escape the engine, the greater the thrust of the rocket.**

Putting Newton's laws of motion together to explain rocket propulsion

An unbalanced force must be exerted for a rocket to lift off from a launch pad (first law). The amount of thrust (force) produced by a rocket engine will be determined by the mass of rocket propellant that is burned and how fast the gas escapes the rocket (second law). The reaction, or motion, of the rocket is equal to and in an opposite direction from the action, or thrust, from the engine (third law).

Adapted with permission of the National Aeronautics and Space Administration from a preliminary draft of the teaching guide *Rockets* by Gregory L. Vogt, NASA Aerospace Education Services.

Top View of Major Units of Space-Shuttle Propulsion System



Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

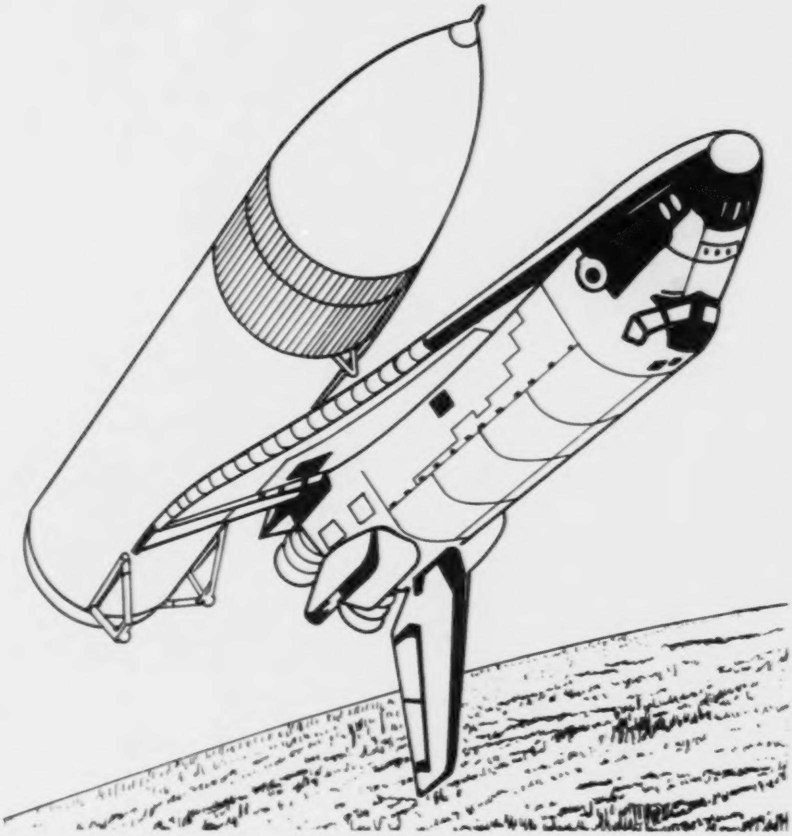
TM 1

342

343

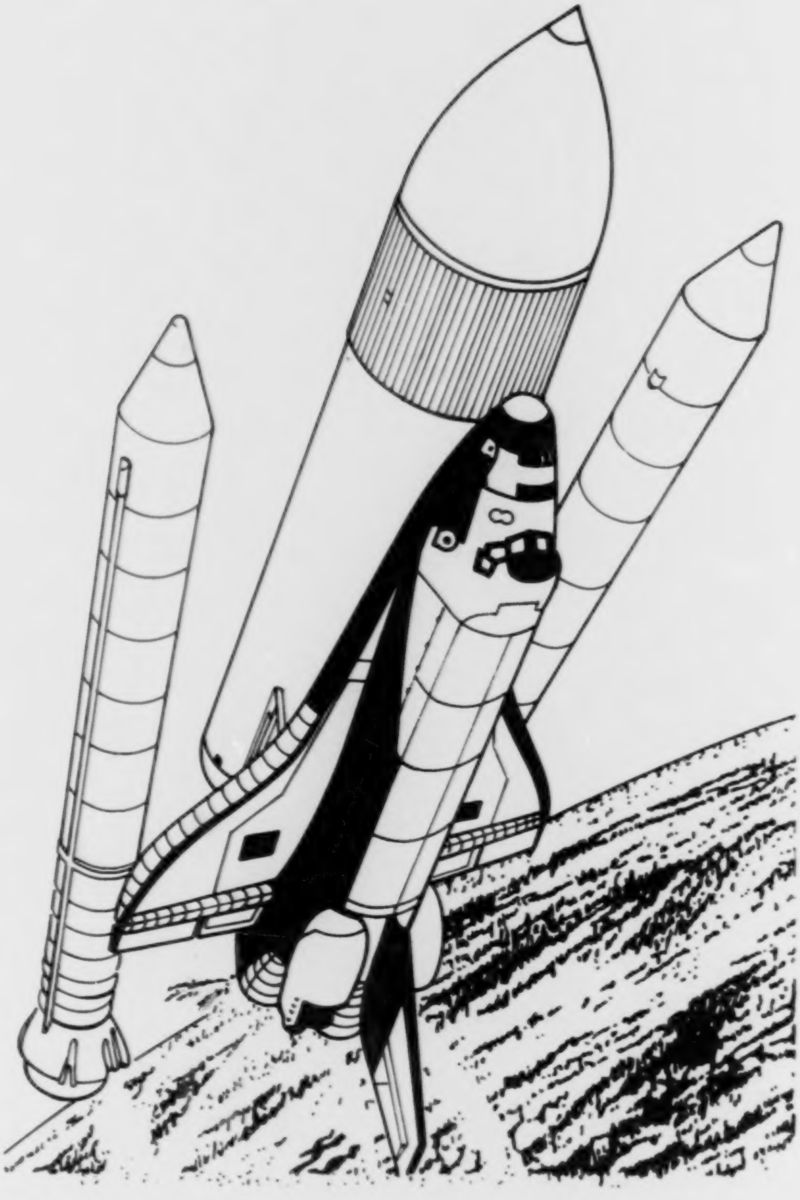
EAS-363

Separation of External Tank



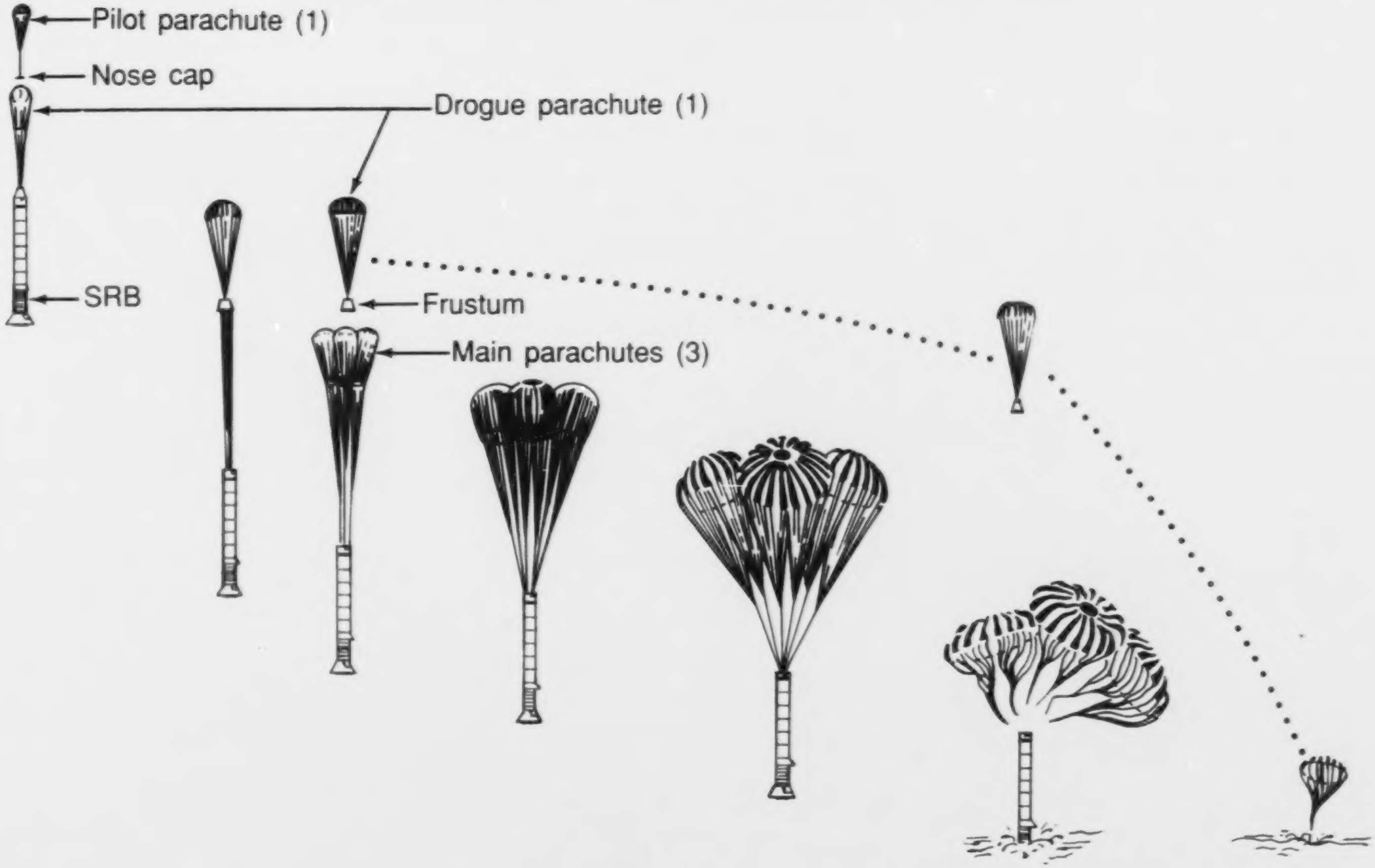
Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

Separation of Solid-Rocket Boosters



Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

SRB Parachute Deployment


Pilot parachute (1)
Nose cap
Drogue parachute (1)
SRB
Frustum
Main parachutes (3)

Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

INFORMATION SHEET

1. **Terms and definitions associated with propulsion systems**

   a. **Propellant**—Fuel plus an oxidizer that when ignited produces rapidly expanding gases that propel a rocket

   b. **Oxidizer**—Agent used to support the combustion of a rocket propellant

   (NOTE: In order for a propellant to burn, oxygen must be present. In space, there is no oxygen. Therefore, rockets must carry an oxidizer—their own oxygen supply.)

2. **Types of rocket propulsion systems and their definitions**

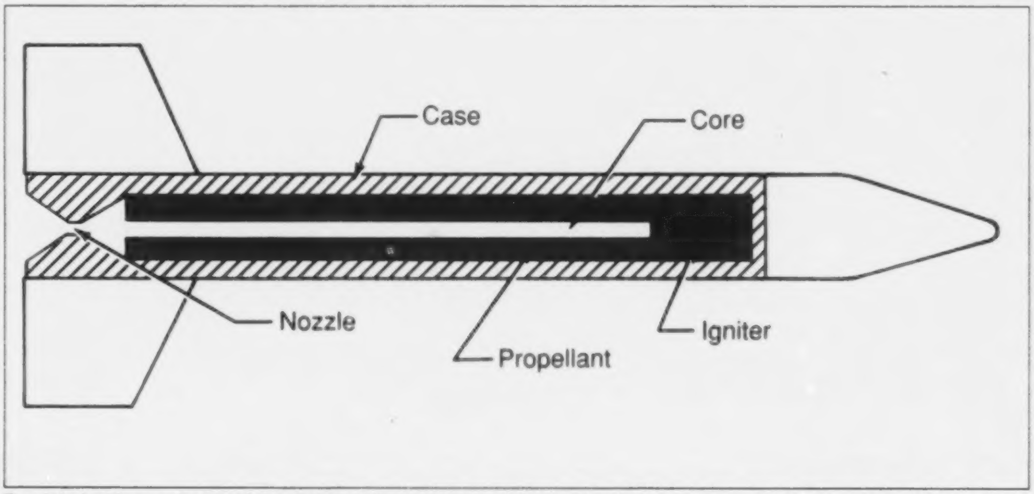
   a. Liquid-propellant—Rocket type that uses a liquid or gas propellant in the propulsion system

   b. Solid-propellant—Rocket type that uses a solid-compound propellant in the propulsion system

3. **Parts of a solid-propellant rocket engine and their definitions** (Figure 1)

   (NOTE: A solid-propellant rocket engine is the simpler of the two types of rocket propulsion systems.)

   FIGURE 1



Reprinted with permission of the National Aeronautics and Space Administration from *NASA Educational Briefs*, "Solid Propellant Rockets," EB-81-7.

   a. Igniter—Storage and combustion area for agents used to ignite solid propellant

INFORMATION SHEET

b. Case—Storage and combustion area for solid propellant

(NOTE: The case usually also includes some form of insulation that protects the case and nozzle from the hot gases formed during combustion of the solid propellant.)

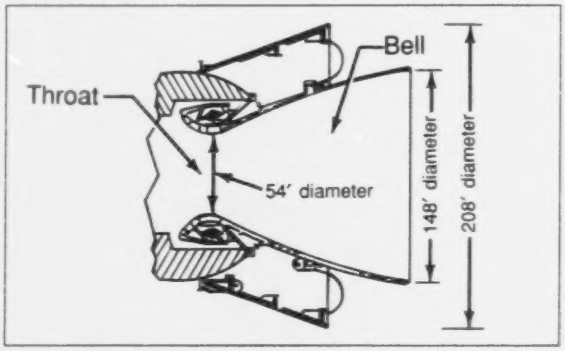
c. Propellant—Solid fuel and an oxidizer compound

d. Core—Narrow passageway where hot gases from combustion of solid propellant are channeled through case

e. Nozzle—Gas-expansion device through which hot gases from combustion flow

(NOTE: The nozzle consists of two parts, the throat and the bell. See Figure 2.)

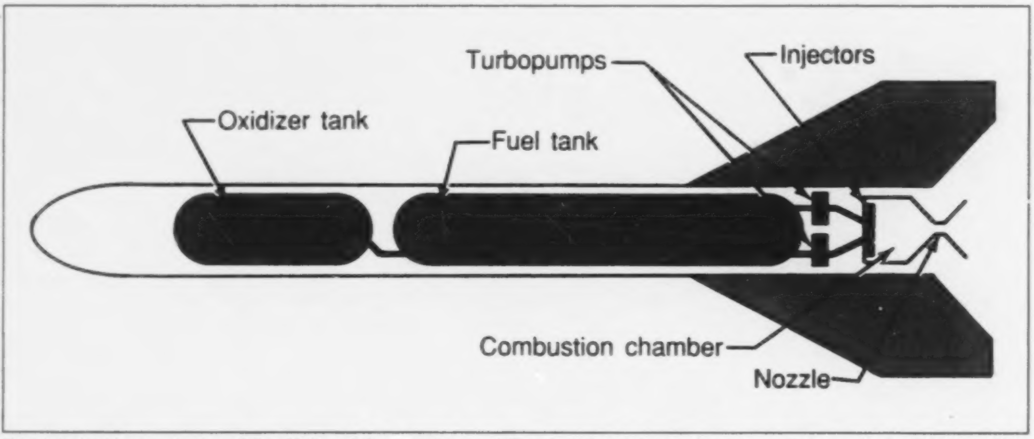
FIGURE 2


Throat
Bell
54′ diameter
148′ diameter
208′ diameter

Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

4. **Parts of a liquid-propellant rocket engine and their definitions** (Figure 3)

FIGURE 3


Turbopumps
Injectors
Oxidizer tank
Fuel tank
Combustion chamber
Nozzle

Reprinted with permission of the National Aeronautics and Space Administration from a preliminary draft of the teaching guide *Rockets* by Gregory L. Vogt, NASA Educational Services.

INFORMATION SHEET

a. Oxidizer tank—Storage area for oxidizer

(NOTE: Liquid oxygen is the oxidizer usually used in liquid-propellant rocket engines.)

b. Fuel tank(s)—Storage area for liquid fuel

(NOTE: To produce a propellant that burns efficiently, the oxidizer and the fuel must be mixed by some means.)

c. Turbopumps—Devices that force liquid fuel and liquid oxidizer from their storage tanks and into the injector areas of the rocket

d. Injectors—Devices that mix liquid oxidizer and liquid fuel to create propellant and then force propellant into rocket's combustion chamber

e. Combustion chamber—Chamber where propellant is burned

f. Nozzle—Gas-expansion device through which hot gases from combustion flow

5. **Principle of rocket propulsion** (Figure 4)

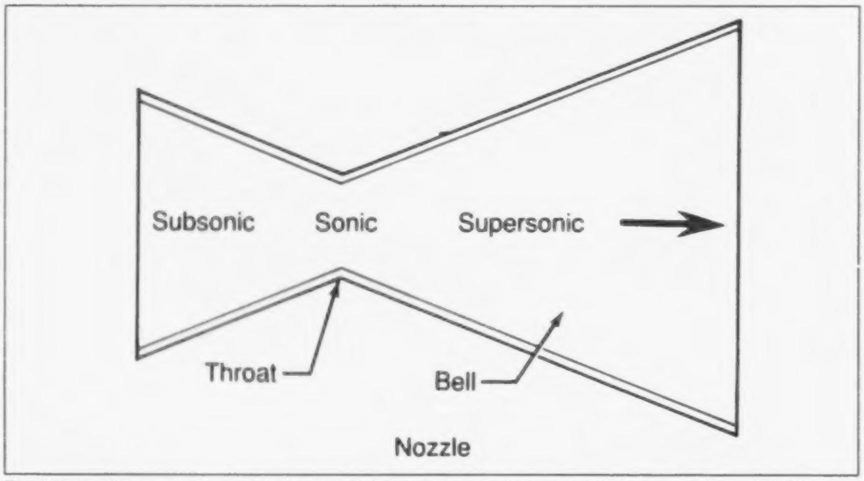
a. Burning of rocket propellant within combustion chamber produces very hot high-pressure gases

b. High chamber pressure produced by propellant combustion forces gases through engine nozzle

c. The **action** of expelling gases in one direction causes a **reaction** that thrusts engine in opposite direction

d. The mass and velocity of exhaust gases determine amount of force of resultant thrust

FIGURE 4



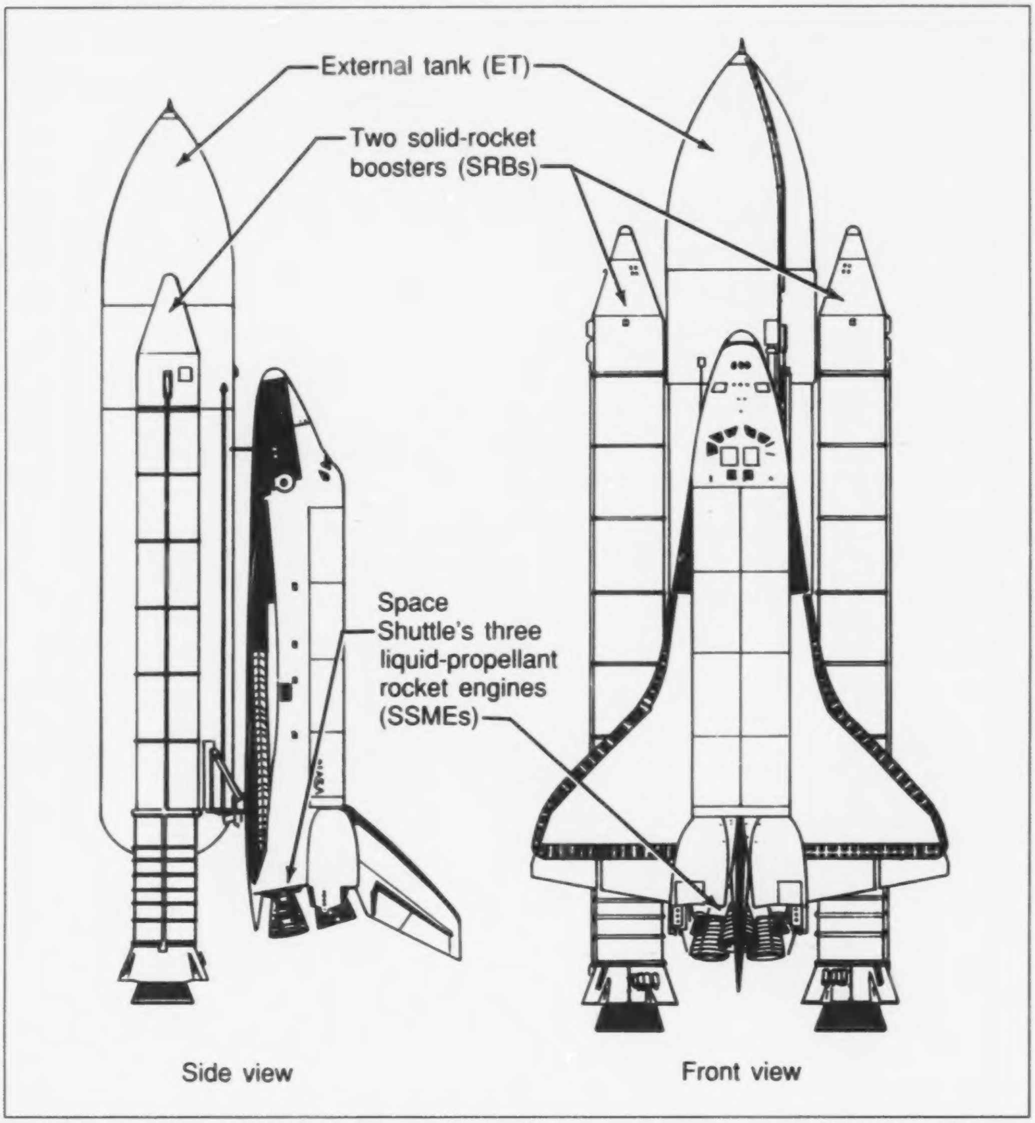
Reprinted with permission of the National Aeronautics and Space Administration from *NASA Educational Briefs*, "Solid Propellant Rockets," EB-81-7.

INFORMATION SHEET

6. **Major units of the Space Shuttle's propulsion system** (Figure 5)

(NOTE: The Space Shuttle's propulsion system consists of three major units: the Shuttle's three main liquid-propellant rocket engines [SSMEs], the external tank [ET], and the motors of the two solid-rocket boosters [SRBs]. The three Shuttle engines are fed propellants from the ET, and the Shuttle's engines, in conjunction with the SRBs, provide the thrust to lift the Shuttle off the ground for the craft's initial ascent.)

FIGURE 5


External tank (ET)
Two solid-rocket boosters (SRBs)
Space Shuttle's three liquid-propellant rocket engines (SSMEs)
Side view
Front view

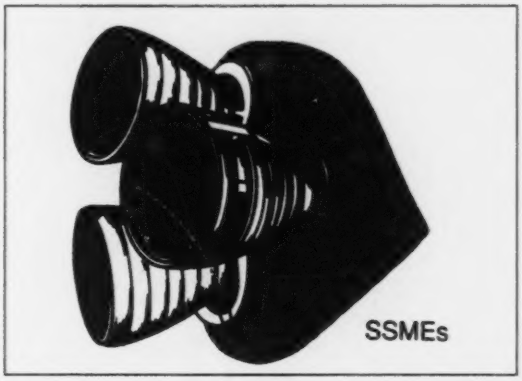
Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

INFORMATION SHEET

7. **Major components of the Space Shuttle's main engines (SSMEs)** (Figure 7)

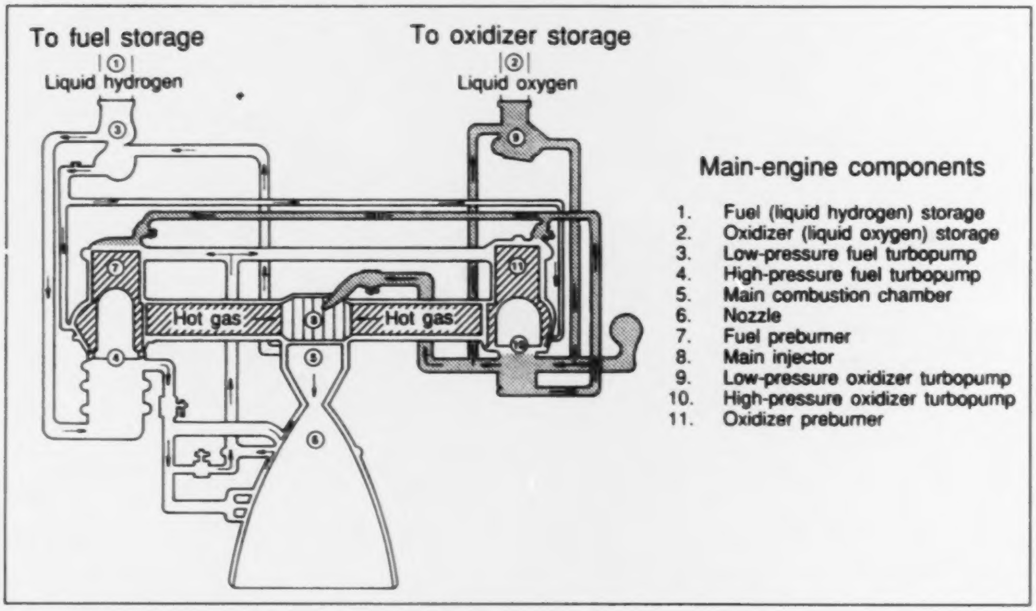
(NOTE: A cluster of three Space Shuttle main engines [see Figure 6] provides the main propulsion force for the vehicle. The high-performance liquid-hydrogen/liquid-oxygen rocket engine used in the Shuttle is reusable and capable of various thrust levels. Ignited on the ground prior to launch, the engine cluster operates in parallel with the solid-rocket boosters during the first two minutes of flight. After the SRBs separate, the Shuttle engines continue to operate for approximately the first 8.5 minutes of flight.)

FIGURE 6



Figures 6 and 7 reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

FIGURE 7



Main-engine components

1. Fuel (liquid hydrogen) storage
2. Oxidizer (liquid oxygen) storage
3. Low-pressure fuel turbopump
4. High-pressure fuel turbopump
5. Main combustion chamber
6. Nozzle
7. Fuel preburner
8. Main injector
9. Low-pressure oxidizer turbopump
10. High-pressure oxidizer turbopump
11. Oxidizer preburner

INFORMATION SHEET

8. **Major components of the external tank (ET)** (Figure 8)

(NOTE: The external tank is the "gas tank" for the Space Shuttle—it contains the fuel and oxidizer used by the main rocket engines during liftoff. Approximately 8.5 minutes into the flight with most of its propellant used, the ET is jettisoned, and then breaks up and splashes down in the Indian Ocean. The ET is the only major unit of the Shuttle's propulsion system that is not reused.

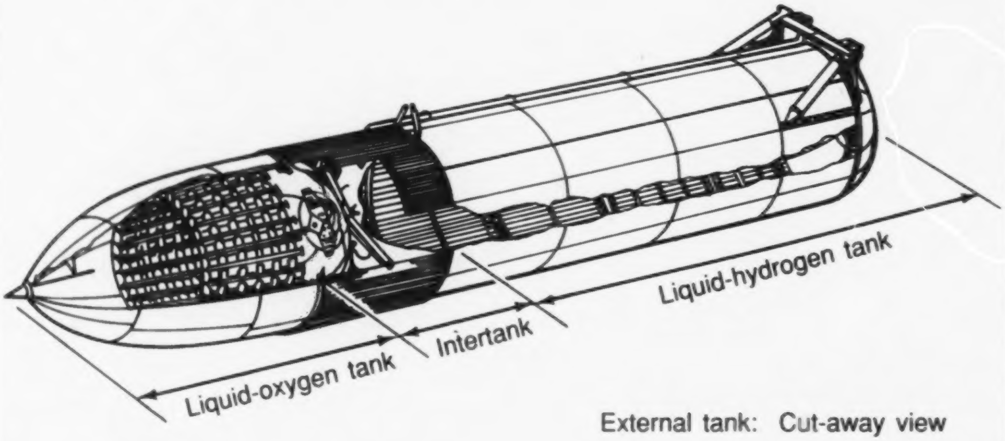
The ET unit consists of three major components: a liquid-oxygen tank, a liquid-hydrogen tank, and an intertank.

The liquid-oxygen tank contains 541,482 liters [143,060 gallons] of oxidizer. It is 16.3 meters [53.5 feet] long and 8.4 meters [27.5 feet] in diameter. The weight, when empty, is 5695 kilograms [12,555 pounds]; loaded, it weighs 622,188 kilograms [1,371,697 pounds].

The liquid-hydrogen tank is the largest component of the ET. Its primary functions are to hold 1,449,905 liters [383,066 gallons] of liquid hydrogen and to provide a mounting platform for the Shuttle and the SRBs. The structure is 29.9 meters [97 feet] long and 8.4 meters [27.5 feet] in diameter. It is composed of a series of barrel sections, domes, and ring frames. The weight, when empty, is 14,402 kilograms [31,750 pounds]; loaded, it weighs 1,107,020 kilograms [257,987 pounds].

The intertank is not actually a tank. It serves as a mechanical connection between the liquid-oxygen and liquid-hydrogen tanks. The intertank is a 6.9-meter [22.5-foot] long cylinder.)

FIGURE 8



External tank: Cut-away view

Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

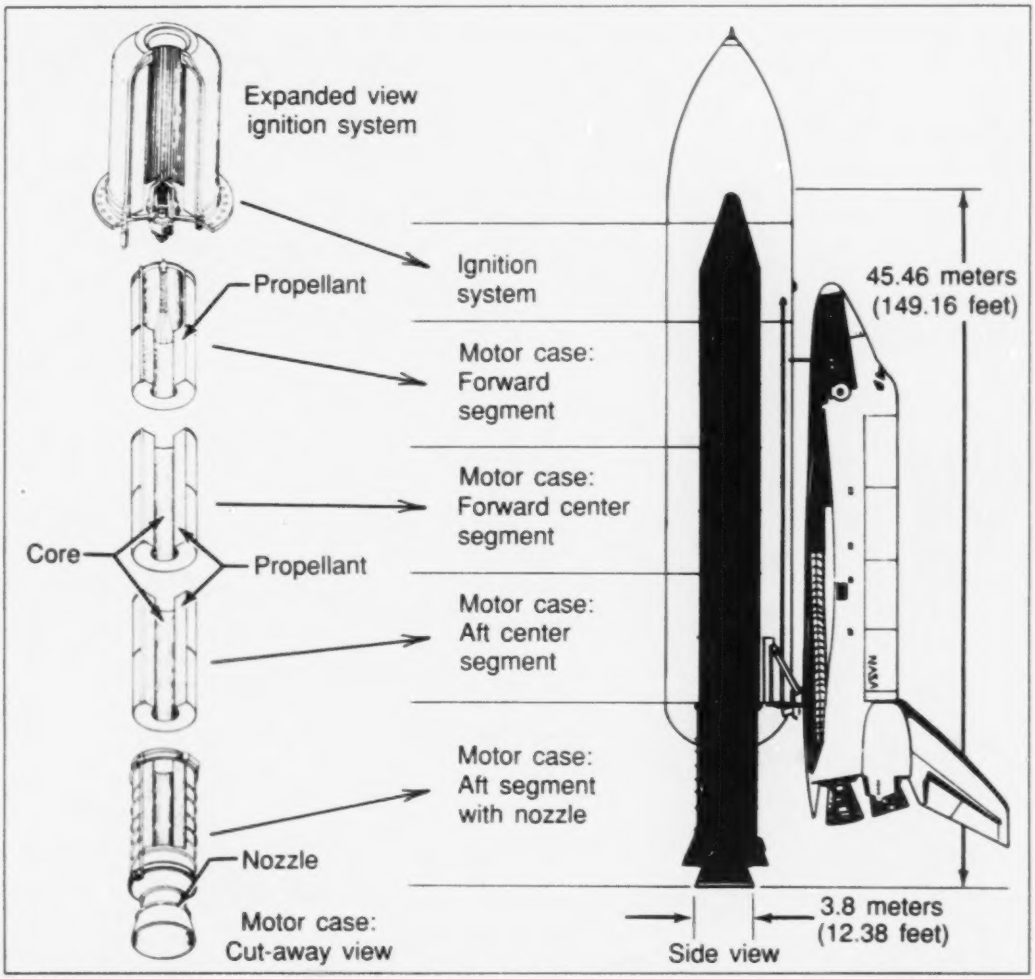
INFORMATION SHEET

9. **Major components of the Space Shuttle's solid-rocket boosters (SRBs)** (Figure 9)

(NOTE: Two solid-rocket boosters operate in parallel with the SSMEs to augment the thrust of the Shuttle's engines from the launch pad through the first two minutes of powered flight. The SRBs also assist in guiding the entire vehicle during the initial ascent. At an altitude of approximately 45 kilometers [24 nautical miles], the SRBs separate from the Shuttle, descend on parachutes, and land in the Atlantic Ocean, where they are recovered by ship. Then the SRBs are returned to land and refurbished for reuse.

The heart of a SRB is the solid-rocket motor [SRM]. The huge SRM is composed of an ignition system, a segmented motor case loaded with solid propellants, and a movable nozzle.)

FIGURE 9


Expanded view ignition system
Propellant
Ignition system
Motor case: Forward segment
Motor case: Forward center segment
Core
Propellant
Motor case: Aft center segment
Motor case: Aft segment with nozzle
Nozzle
Motor case: Cut-away view
45.46 meters (149.16 feet)
3.8 meters (12.38 feet)
Side view
NASA

Reprinted with permission of the National Aeronautics and Space Administration from *Space Shuttle News Reference*, n.d.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

STUDENT SUPPLEMENT 1—SOLID-PROPELLANT ROCKETS

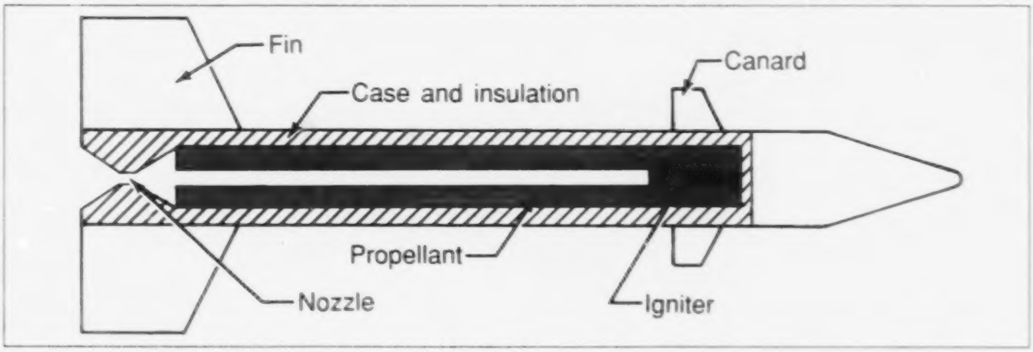
A major share of the liftoff thrust for the Space Shuttle is generated by two solid-propellant rocket boosters. Although the boosters are the largest solid-propellant rockets ever built, the first used to launch astronauts into space, and the first designed for reuse, they actually represent some of the oldest technology carried by the Space Shuttle. In principle, these boosters are very similar to the solid-propellant rockets used in China at least 750 years ago. Those rockets consisted of a capped leather cylinder that was filled with an early version of gunpowder and mounted on a stick. When ignited, the burning powder produced rapidly expanding gases that propelled the rocket and stick through the air. The primitive Chinese rockets found application in warfare and as fireworks displays in festive celebrations.

From the invention of the first solid-propellant rocket to the 1950s, development of solid-rocket technology had been extraordinarily slow. Since the 1950s, a number of advancements have taken place in construction materials and propellants used and in flight stability and guidance controls, but the basic rocket design has remained essentially the same.

Solid-propellant rockets in use today consist of a solid fuel and oxidizer compound with the following associated hardware (see Figure 1):

- **Case**—High-pressure gas container that encloses the propellant
- **Nozzle**—Gas expansion device through which the rocket exhaust flows
- **Insulation**—Protection for the case and nozzle from hot gases
- **Igniter**—Device that starts the combustion of the propellants
- **Stabilizers** (fins and canards)—Directional-control system during flight.

FIGURE 1



STUDENT SUPPLEMENT 1

Propellants

Solid propellants, commonly referred to as the "grain," are basically a chemical mixture or compound containing a fuel and oxidizer that burn to produce very hot gases at high pressure. They burn without the introduction of outside oxygen.

Solid propellants fall into three basic classes: monopropellants, double base, and composites. *Monopropellants* are energetic compounds such as nitroglycerin or nitrocellulose. Both compounds contain fuel (carbon and hydrogen) and oxidizer (oxygen). Monopropellants are rarely used in modern rockets. *Double-base propellants* are mixtures of monopropellants such as those listed above. The nitrocellulose adds physical strength to the grain while the nitroglycerin is a high-performance, fast-burning propellant. Usually double-base propellants are mixed together with additives that improve the burning characteristics of the grain. The mixture becomes a putty-like material that is loaded into the rocket case.

Composite propellants are formed from mixtures of two or more unlike compounds that by themselves do not make good propellants. Usually one compound is the fuel and the other is the oxidizer. The propellants used in the solid-rocket boosters of the Space Shuttle fall into this class. The propellant type used there is known as PBAN, which is an abbreviation of the term *polybutadiene acrylic acid acrylonitrile terpolymer.* This exotic-sounding chemical is used as a binder for ammonium perchlorate (oxidizer), powered aluminum (fuel), and iron oxide as an additive. The cured propellant looks and feels like the hard rubber of a typewriter eraser.

Design

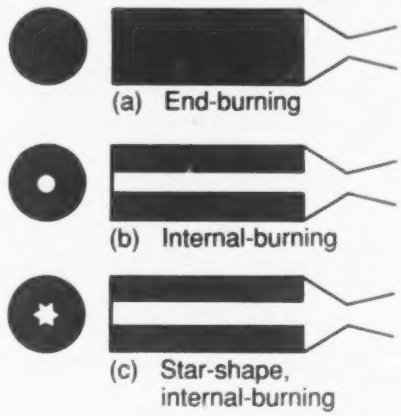
The thrust produced by the propellants is determined by the combustive nature of the chemicals used and by the shape of their exposed burning surfaces. A solid propellant will burn at any point that is exposed to heat or hot gases of the right temperature. Grains are usually designed to be either end-burning or internal-burning.

End-burning grains (see Figure 2-a) burn the slowest of any grain design. The propellant is ignited close to the nozzle and the burning proceeds the length of the propellant load. The area of the burning surface is always at a minimum. While the thrust produced by end burning is lower than for other grain designs, the thrust is sustained over longer periods.

Much more massive thrusts are produced by *internal burning.* In this design (see Figure 2-b), the grain is pierced by one or more hollow cores that extend the length of the case. The surface of the cores is much larger than the surface exposed in end-burning grain. The entire surfaces of the cores are ignited at the same time and burning proceeds from the inside out. To increase the surface available for burning, a core may be shaped into a star design. See Figure 2-c.

The Space Shuttle boosters feature a single core that has an eleven-point star design in the forward section. At 65 seconds into the launch, the star points are burned away and thrust temporarily diminishes. This coincides with the passage of the Space Shuttle through the sound barrier. Buffeting occurs during this passage and the lowered thrust reduces strain on the vehicle.

FIGURE 2



Grain design

Case

The rocket case is the pressure- and load-carrying structure that encloses the propellant. Cases are usually cylindrical, but some are spherical in shape. The case is an inert part of the rocket and its weight is an important factor in determining how much payload and how far the rocket can travel. High-performance rockets require that the casing be constructed of the lightest materials possible.

Alloys of steel and titanium are commonly used for solid-rocket casings. Upper-stage vehicles may use thin metal shells that are wound with fiberglass for extra strength.

STUDENT SUPPLEMENT 1

The Shuttle boosters use steel walls that average 1.27 centimeters in thickness. For convenience in reloading these boosters, they are assembled from four large segments. After ocean recovery, the segments are separated and transported by rail to a loading facility.

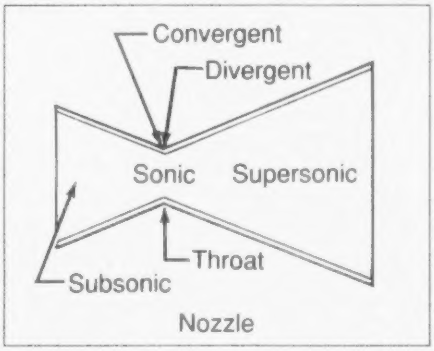
Insulation

Unless protected by insulation, the solid-rocket motor case will rapidly loose strength and burst or burn through. To protect the casing, insulation is bonded to the inside wall of the case before the propellant is loaded. The thickness of the insulation is determined by how long the casing is exposed to high-pressure, hot gases. A frequently used insulation for solid rockets is an asbestos-filled rubber compound that is heat-bonded to the casing wall.

Nozzle

During the combustion process, the resulting high-temperature and high-pressure gases exit the rocket through a narrow opening, called the *nozzle*, which is located at the lower end of the motor. See Figure 3. The most efficient nozzle designs are convergent-divergent. The narrowest part of the nozzle is the throat. Escaping gases flow through this construction with relatively high velocity and temperature. Heat transfer to the wall is a great problem in this location. Protection for the throat consists of a liner that either withstands high temperatures or ablates (erodes and carries away) the heat. The Shuttle boosters rely on ablative materials to protect the throat.

FIGURE 3



During operation, gas velocity in the convergent part of the nozzle is subsonic. Gas velocity increases to sonic speeds at the throat and to supersonic speeds in the divergent portion.

STUDENT SUPPLEMENT 1

Igniter

To ignite the propellants of a solid rocket, the grain surface must be bathed with hot gases. The igniter is usually a rocket motor itself but much smaller in size. The igniter may be placed inside the upper end of the hollow core, as it is with the Shuttle boosters, at the lower end of the core, or outside the rocket. In this last case, the exhaust of the igniter is directed into the nozzle of the larger rocket.

An electrical circuit with a hot-wire resistor or an exploding bridgewire starts the igniter. Initial ignition begins with fast-burning pellets that, in turn, fire up the main igniter propellants.

Stability

Active directional control of solid rockets in flight is generally accomplished by one or two means. Fins and possibly canards (small fins on the fore end of the casing; see Figure 1) many be mounted on the rocket's exterior. During flight these structures tilt to steer the rocket in much the same way that a rudder on a boat operates. While operating, canards have an opposite effect on the directional changes of the rocket from the effect produced by the fins.

A second directional control that may be employed is a tiltable or gimballed nozzle. Slight changes in the direction of the exhaust are accomplished by reaming the nozzle to move from side to side. The Space Shuttle boosters use this method for steering.

Advantages and disadvantages

When compared to liquid-rocket systems, solid-propellant rockets offer the advantage of simplicity and reliability. With the exception of stability controls, solid rockets have no moving parts to fail during flight. When loaded with propellant and erected on a launch pad, solid rockets can be ready for firing at a moment's notice. Liquid-propellant motors require extensive pre-launch preparation.

Solid rockets also have the advantage of having a greater portion of their total mass consist of propellants. Liquid engines require propellant feed lines, pumps, and cooling systems, all adding additional inert weight to the vehicle.

Rocket engineers, when considering vehicle performance, talk of *mass fraction*. This is a numerical measure of the vehicle's propellant mass divided by its total mass. For an ideal rocket, the mass fraction would be approximately 0.91 to 0.93. In other

STUDENT SUPPLEMENT 1

words, 91 to 93 percent of the total rocket weight is propellant and the rest is payload, tanks or casing, and engines. Liquid engines, even with thin-wall tanks, can barely achieve a 0.90 mass fraction.

The Space-Shuttle boosters, because they are being used to launch astronauts into space and then recovered from the ocean after parachute splashdown, have a mass fraction of just under 0.86. A weight penalty is paid through increased design safety margins and the inclusion of a parachute-recovery system.

The principle disadvantage of solid rockets has to do with the burning characteristics of their propellants. Solid propellants are typically less energetic (deliver less thrust to their mass) than the best liquid propellants. Once ignited, the propellants burn rapidly and are extremely hard to throttle or extinguish. Liquid-propellant engines can be started and stopped at will, making them excellent for use in space where carefully measured thrusts become necessary for course changes.

Uses

Solid-propellant rockets are used by NASA as boosters for the Space Shuttle. A new solid-rocket booster is being developed to be carried in the cargo bay of the Space Shuttle for use as an upper-stage vehicle.

Caution

In spite of their apparent simplicity, solid-propellant rocket motors are very dangerous when constructed by amateurs. Literally hundreds of students, teachers, and home experimenters have been seriously injured by exploding rockets. Propellant packing density, burning rate, case bursting strength, and nozzle construction are design problems beyond the scope of most amateur experimenters.

Student Supplement 1 adapted with permission of the National Aeronautics and Space Administration, Washington, D.C., from National Educational Briefs, "Solid Propellant Rockets,", EB-81-7.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

STUDENT SUPPLEMENT 2—LIQUID-PROPELLANT ROCKETS

In the history and development of rocketry, liquid-propellant rockets have played a highly important, though relatively brief role. A rudimentary understanding of some of the principles of rocketry and their application was known at least 2000 years ago, although the first flights of rockets, as we know them, were considerably more recent. The invention of solid-propellant rocketry is generally credited to 11th-century China. The invention of liquid-propellant rockets, however, came much later in the United States in 1926. In that year, a young scientist, Robert H. Goddard, successfully launched the first liquid-propellant rocket. Like the first flight of the Wright Brothers in 1903, Goddard's rocket was impressive only because it was the first of its kind. The gasoline-and-liquid-oxygen rocket climbed only 18.3 meters and landed down range in a cabbage patch 56 meters away.

Goddard continued his work on liquid-propellant rocketry for many years, eventually moving from his aunt's farm in New England to Roswell, New Mexico. Goddard not only pioneered liquid-propellant rocketry but many of his innovations in engine technology are still being employed today. So important were his contributions to the field it has been said that "Every liquid-propellant rocket is a Goddard Rocket."

From the work of Robert Goddard to the flights of the Space Shuttle, liquid-propellant rocket engines have played an important role in space research. Most rockets capable of carrying satellites to space and every rocket used to carry astronauts into space have relied upon liquid-propellant engines. These engines, while much more complicated than solid-propellant motors, offer important advantages for space flight. Liquid engines can be started and stopped by starting or stopping the flow of propellants. Solid-propellant rockets are extremely difficult to extinguish once ignited. Many liquid-propellant engines can be throttled to any desired thrust. Adjusting the thrust of the solid-propellant motors requires shaping the burning surface of the propellant before launch to promote a more or less vigorous burn during flight.

Parts of liquid-propellant rockets

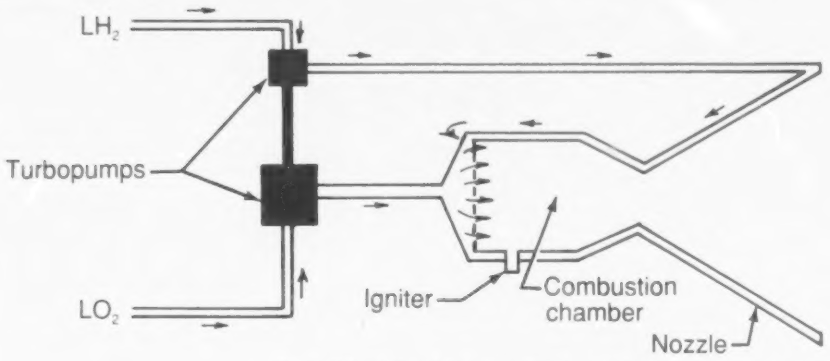
Liquid-propellant rockets have four principal parts in their propulsion systems (see Figure 1):

- **Propellant tank(s)**—Load-bearing structure that contains the liquid propellants.
- **Combustion chamber**—The chamber where propellants are burned.

STUDENT SUPPLEMENT 2

- **Nozzle**—Gas-expansion device through which the rocket exhaust flows.
- **Turbopump**—Device for delivering propellants from the propellant tanks to the chamber at high pressure. (In some rockets, turbopumps are eliminated by using pressure in the tanks to force propellants to the chamber.)

FIGURE 1



Simplified liquid-propellant engine

Propellant tanks

The function of propellant tanks is simply the storage of one or two propellants until needed in the combustion chamber. Depending upon the kind of propellants used, the tank may be nothing more than a low-pressure envelope or it may be a pressure vessel for containing high-pressure propellants. In the case of cryogenic propellants, propellants at extremely low temperatures, the tank has to be an exceptionally well-insulated structure to keep propellants from boiling away.

As with all rocket parts, weight of the propellant tanks is an important factor in their design. Stated simply, the lighter the propellant tank (or other rocket part), the greater the payload that can be carried or the higher the rocket can climb. Many liquid-propellant tanks are made out of very thin metal or are thin metal sheaths wrapped with high-strength fibers and cements. These tanks are stabilized by the internal pressure of their contents, much the same way balloon walls gain strength from the gas inside. Very large propellant tanks and tanks that contain cryogenic propellants require additional strengthening or layers. Structural rings and ribs are used to strengthen tank walls, giving the tanks the appearance of an aircraft frame. With cryogenic propellants, extensive insulation is needed to keep the propellants in their liquified form. Even with the best insulation, cryogenic propellants are difficult to keep for long periods of time and will boil away. For this reason, cryogenic propellants are usually not used with military rockets, which must be kept in a ready state for launch for many months at a time.

The propellant tanks of the Space Shuttle serve as an excellent example of the complexities involved in propellant-tank design. The external tank or ET, as the liquid-propellant tanks of the Shuttle system are called, consists of two smaller tanks and an intertank. The ET is the structural backbone of the Space Shuttle and during launch it must bear the entire thrust produced by the solid-rocket boosters and the Orbiter main engines.

The forward, or *nose tank*, contains liquid oxygen (LO_2) at a temperature of 90 kelvins (–183 degrees C). It is 16.3 meters long and 8.4 meters in diameter at its widest dimension. The nose end of the tank is tapered to an ogive (pointed-arch) shape. Anti-slosh and anti-vortex baffles are installed inside the LO_2 tank as well as inside the other tank to prevent gas bubbles inside the tank from being pumped to the engines along with the propellants. Many rings and ribs strengthen this tank.

The second tank contains liquid hydrogen (LH_2) at a temperature of 20 kelvins (–253 degrees C). This tank, with a length of 29.9 meters and a diameter of 8.4 meters, is 2½ times the size of the LO_2 tank. However, the LH_2 tank weighs only one third as much as the LO_2 tank because liquid oxygen is 16 times heavier than liquid hydrogen. This tank has numerous rings, ribs, and two longerons to distribute Orbiter thrust loads.

Between the two tanks is an intertank structure. The intertank is not actually a tank but a mechanical connection between the LO_2 and LH_2 tanks. Its primary function is to join the two tanks together and distribute thrust loads from the solid-rocket booster. The intertank also houses a variety of instruments.

Covering the entire surface of the ET is a layer of polyiscyanurate foam insulation. This foam, which is brownish in appearance and gives the ET its color, insulates the propellants to reduce boiling and prevents aerodynamic heat generated during the flight from reaching the propellants.

Turbopumps

Turbopumps provide the required flow of propellants from the low-pressure propellant tanks to the high-pressure rocket chamber. Power for the pumps is produced by combusting a fraction of the propellants in a preburner. Expanding gases from the burning propellants drive one or more turbines which, in turn, drive the turbopumps. After passing through the turbines, exhaust gases are either directed out of the rocket through a nozzle or are injected, along with liquid oxygen, into the chamber for more complete burning. The main engines of the Space Shuttle Orbiter add the preburner gases to the combustion chamber.

Combustion chamber and nozzle

The combustion chamber of a liquid-propellant rocket is a bottle-shaped container with openings at opposite ends. The openings at the top inject the propellants into the chamber. Each opening consists of a small nozzle that injects either fuel or oxidizer. The main purpose of the injectors is to mix the propellants to insure smooth and complete combustion and no detonations. Combustion-chamber injectors come in many designs and one engine may have hundreds. The main engines of the Space Shuttle have 600 injectors each.

After the propellants have entered the chamber, they must be ignited. Hypergolic propellants ignite on contact, but other propellants need a starter device such as a spark plug. Once combustion is started, heat in the chamber continues the process.

The hole at the opposite end (lower end) of the chamber is the throat, or narrowest part of the nozzle. Combustion of the propellants builds up gas pressure inside the chamber, which then exhausts through the nozzle. By the time the gas leaves the exit cone (widest part of the nozzle), it achieves supersonic velocity and imparts forward thrust to the vehicle.

Because of high temperatures produced by propellant combustion, the chamber and nozzle must be cooled. The combustion chambers of the Shuttle Orbiter's main engines reach 3590 kelvins (3315 degrees C) during firing. All surfaces of the chamber and nozzle need to be protected from the eroding effects of the high-temperature, high-pressure gases. Two approaches to cooling the chamber and nozzle can be taken. One approach is identical to the cooling of many solid-propellant rocket nozzles. The surface of the nozzle is covered with ablative materials that evaporate in the high-temperature gas stream, cooling the surface underneath. However, this method adds extra weight to a liquid-propellant engine, which reduces payload or range capability of the vehicle. Because of all the other hardware associated with liquid-propellant engines, also adding weight, ablative cooling is used only where the engine is small or a simplified engine design is more important than high performance.

STUDENT SUPPLEMENT 2

The second method of cooling, one that is used with the Shuttle's main engines, is regenerative cooling. A complex plumbing arrangement inside the combustion and nozzle chamber walls circulates the super cold LH_2 fuel before it is sent through the preburner. LH_2 absorbs some of the heat produced in the combustion chamber thereby making it possible to use thin, lightweight metals for the walls. Although more complicated than ablative cooling, regenerative cooling reduces the weight of large rocket engines, and improves flight performance.

Propellants

Propellants for liquid rockets normally fall into two categories: monopropellants and bipropellants. *Monopropellants* consist of a fuel and an oxidizing agent stored in one container. They can be two premixed chemicals such as alcohol and hydrogen peroxide or a homogeneous chemical such as nitromethane. Another chemical, hydrazine, becomes a monopropellant when first brought into contact with a catalyst. The catalyst initiates a reaction that produces heat and gases from the chemical decomposition of the hydrazine.

Bipropellants have the fuel and oxidizer separate from each other until they are mixed in the combustion chamber. Commonly used bipropellants include LO_2 and kerosene, LO_2 and LH_2, and monomethylehydrazine and nitrogen tetroxide. The last bipropellant, abbreviated to MMH and N_2O_4, is hypergolic. *Hypergolic* means it ignites instantaneously upon contact. This property makes hypergolic propellants especially useful for attitude-control rockets where frequent firings and high reliability are required.

Propellants used in the Space Shuttle Orbiter include LO_2 and LH_2 for the three main engines and hypergolic MMH and N_2O_4 in the orbital maneuvering system engines.

Caution

Constructing liquid-propellant rocket engines is a very dangerous activity when participated in by amateurs. Literally hundreds of students, teachers, and home experimenters have been seriously injured by exploding rockets. Propellant performance, chamber bursting strength, and nozzle shape are design and construction problems beyond the scope of most amateur experimenters.

Student Supplement 2 reprinted with permission of the National Aeronautics and Space Administration, Washington, D.C., from *NASA Educational Briefs*, n.d.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

STUDENT SUPPLEMENT 3—COMMON ROCKET PROPELLANTS

Liquid-propellant fuels

- Ethyl alcohol
- Hydrazine
- RP-1 (kerosine)
- Hydrogen
- Liquid oxygen
- Alcohol
- Aerozine
- UDMH (unsymmetrical dimethyl hydrazine)
- Metallic hydrides
- Liquid hydrogen
- Ammonia
- Various amines
- Various hydrocarbons

Solid-propellant fuels

- Asphalt resins
- Rubber resins
- Plastic resins
- Gunpowder
- Nitrocellulose
- Nitroglycerin
- DEGN (Diethylene glycol dinitrate)

Oxidizers

- Oxygen
- Nitrogen tetroxide
- Potassium perchlorate
- Ammonium perchlorate
- Fluorine
- Fluorine compounds
- Nitric acid
- Hydrogen peroxide

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

STUDENT SUPPLEMENT 4—SAFETY PLEDGE

Introduction

It is understood that each student will be given proper instruction in the construction, operation, and safety procedures concerning solid-propellant model rockets. The student must assume the responsibility for following these safe rocketry procedures and will demonstrate his or her intentions of doing so by signing the following safety pledge.

Model Rocketry Safety Pledge

1. I will follow all safety rules in the Solid-Propellant Model-Rocketry Safety Code.
2. I understand that some of the chemicals and propellants I will be working with are dangerous, and in extreme cases if abused, could cause injury or harm.
3. I will report immediately any accident or injury—no matter how minor—to my instructor.

Student's signature ______________________________ Date __________

Instructor's signature ______________________________ Date __________

Parent's or guardian's signature ______________________ Date __________

(Parental/guardian consent is necessary if the student is under the age of 18.)

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

ASSIGNMENT SHEET 1—COMPARE THE PROPULSION SYSTEMS OF SOLID- AND LIQUID-PROPELLANT ROCKETS

Name ______________________________ Score ____________

Exercises

Part A **Solid-propellant rockets**

Directions Read Student Supplement 1 and then answer each of the following questions about solid-propellant rockets.

1. What country is generally credited with the invention of the first primitive rockets 750 years ago?

   Describe these primitive rockets.

   Country ______________________________

   ____

   Description ______________________________

   ____

   ____

   ____

   ____

   ____

2. Why is a solid-propellant rocket the simpler of the two kinds of rockets?

   ____

   ____

   ____

   ____

   ____

   ____

   ____

ASSIGNMENT SHEET 1

3. Diagram the main parts of a solid-propellant rocket.

4. Name and describe the two types of grain designs used in solid-propellant rockets.

5. Which grain design produces the more massive thrust?

ASSIGNMENT SHEET 1

6. Which grain design is used in the Space Shuttle's solid-rocket boosters?

7. How is the nozzle of the Space Shuttle's solid-rocket engine protected from the eroding effects of the high-temperature and pressure stream of exhaust gases?

8. List the three possible placements of the igniters used in solid-propellant rockets.

9. Which igniter placement is used in the Space Shuttle's solid-rocket boosters?

10. Why is constructing solid-propellant rocket engines a dangerous occupation?

ASSIGNMENT SHEET 1

Part B **Liquid-propellant rockets**

Directions Read Student Supplement 2 and then answer the following questions about liquid-propellant rockets.

1. Who is credited with the invention of the first liquid-propellant rocket? In what year was the rocket invented?

   Inventor ____________________

   Year ____________________

2. Diagram the main parts of a liquid-propellant rocket.

3. What is the function of the propellant tanks?

   ____

   ____

   ____

   ____

   ____

   ____

   ____

ASSIGNMENT SHEET 1

4. Why is the weight of the propellant tanks an important design factor?

5. What is the purpose of the turbopumps?

6. How is the power for the turbopumps produced?

7. What is the function of injectors?

ASSIGNMENT SHEET 1

8. What is the function of the igniters?

9. Regenerative cooling is used in the Space Shuttle to cool the combustion chamber and the nozzle. How does regenerative cooling work?

10. What advantage does regenerative cooling have over the cooling method used in the Shuttle's solid-rocket boosters?

11. What propellant is used in the Space Shuttle's liquid-propellant rocket engines?

ASSIGNMENT SHEET 1

12. Why is constructing liquid-propellant rocket engines a dangerous occupation?

Part C **Comparison**

Directions Review Student Supplements 1 and 2 and your answers to the exercises in parts A and B of this assignment sheet; then, answer the following questions.

1. How does a liquid-propellant rocket compare to a solid-propellant rocket?

ASSIGNMENT SHEET 1

2. Why do you think NASA scientists chose to use both solid- and liquid-propellant engines in the design of the Space Shuttle's propulsion system?

Part D **Research**

Directions Select one of the following topics, research your selected topic, and then write a report on that topic. Attach your completed report to this assignment sheet and turn the assignment sheet in to your instructor for evaluation.

1. Research the history of liquid-propellant rockets.
2. Research the history of the development of solid-propellant rockets.
3. Read the listing of rocket fuels given in Student Supplement 3, and then research types of rocket fuels.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

ASSIGNMENT SHEET ANSWERS

Assignment Sheet 1

Part A Solid-propellant rockets

1. Country—China
Description—Those rockets consisted of a capped leather cylinder that was filled with an early version of gunpowder and mounted on a stick.

2. There are only two main components to a solid-propellant rocket: a solid fuel and an oxidizer enclosed in a case.

3. Evaluated to the satisfaction of the instructor

   (EVALUATOR'S NOTE: See Figure 1 in Student Supplement 1.)

4. End-burning grains—The propellant is ignited close to the nozzle and the burning proceeds the length of the propellant load.

   Internal-burning grains—The grain is pierced by one or more hollow cores that extend the length of the case. The entire surfaces of the cores are ignited at the same time and burning proceeds from the inside out.

5. Much more massive thrusts are produced by internal-burning grains.

6. Internal-burning

7. Protection for the throat consists of a liner that ablates (erodes and carries away) the heat.

8. The igniter may be placed inside the upper end of the hollow core, at the lower end of the core, or outside the rocket.

9. The Space Shuttle's igniter is placed inside the upper end of the hollow core.

10. In spite of their apparent simplicity, solid-propellant rocket motors are very dangerous. Propellant packing density, burning rate, case bursting strength, and nozzle construction are design problems beyond the scope of most amateur experimenters.

ASSIGNMENT SHEET ANSWERS

Part B Liquid-propellant rockets

1. Inventor—Robert H. Goddard
   Year—1926

2. Evaluated to the satisfaction of the instructor

   (EVALUATOR'S NOTE: See Figure 1 in Student Supplement 2.)

3. The function of propellant tanks is simply the storage of one or two propellants until needed in the combustion chamber.

4. The lighter the propellant tank, the greater the payload that can be carried or the higher the rocket can climb.

5. The turbopumps provide the required flow of propellants from the low-pressure propellant tanks to the high-pressure rocket chamber.

6. Power for the turbopumps is produced by combusting a fraction of the propellants in a preburner. Expanding gases from the burning propellants drive one or more turbines which, in turn, drive the turbopumps.

7. The main purpose of the injectors is to mix the propellants to insure smooth and complete combustion and no detonation.

8. Igniters are starter devices that act like a spark plug to start combustion of the propellants. Once combustion is started, heat in the combustion chamber continues the process.

9. A complex plumbing arrangement inside the combustion and nozzle chamber walls circulates the super cold LH_2 fuel before it is sent through the preburner. LH_2 absorbs some of the heat produced in the combustion chamber.

10. Although more complicated than the ablative cooling used in the solid-rocket boosters, a regenerative cooling system is lighter.

11. LO_2 and LH_2 is used in the three main engines.

12. Propellant performance, chamber bursting strength, and nozzle shape are design and construction problems beyond the scope of most amateur experimenters.

ASSIGNMENT SHEET ANSWERS

Part C Comparison

1. Evaluated to the satisfaction of the instructor

   (EVALUATOR'S NOTE: Student discussion should include some of the following points.)

   - Solid-propellant rockets are simpler in design than liquid-propellant rockets, and are more reliable. Solid rockets have fewer moving parts to fail during flight, and when loaded with propellant and erected on a launch pad, solid rockets can be ready for firing at a moment's notice.

   - Solid-propellant rockets have a more ideal mass fraction than do liquid-propellant engines.

   - Solid-propellant engines typically deliver less thrust to their mass than the best liquid propellants.

   - Liquid-propellant rockets, while much more complicated than solid-propellant motors, can be started and stopped by starting or stopping the flow of propellants and many liquid-propellant engines can be throttled to any desired thrust, making them excellent for use in space where carefully measured thrusts become necessary for course changes.

2. Evaluated to the satisfaction of the instructor

   (EVALUATOR'S NOTE: Student discussion should include some of the following points.)

   - Solids are denser and heavier than liquids. Solids produce greater mass for the equation f = ma than an equal volume of liquid propellant.

     The solids produce greater thrust while the liquids provide better control at later periods of a flight. Liquid fuels also have the ability to be turned on and off.

Part D Research

Evaluated to the satisfaction of the instructor

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

LAB ACTIVITY SHEET 1—SIMULATE A MULTI-STAGE ROCKET LAUNCH

Introduction

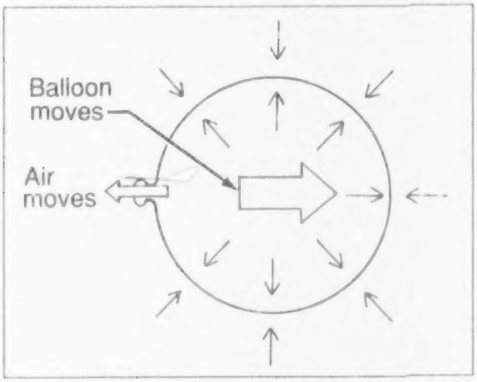
Travel into outer space takes enormous amounts of energy. Much of that energy is used to lift rocket propellants that will be used for later phases of the rocket's flight. To eliminate the technological problems and cost of building giant one-piece rockets to reach outer space, NASA, as well as all other space-faring nations of the world, have chosen to use a rocket technique that was invented by 16th-century fireworks-maker Johann Schmidlap. To reach higher altitudes with his aerial displays, Schmidlap attached smaller rockets to the top of larger ones. When the larger rockets were exhausted, the smaller rocket climbed to even higher altitudes. Schmidlap called his invention a "step rocket."

Today's Space-Shuttle propulsion system makes use of Schmidlap's invention through a process called *multi-staging*. During Stage 1, the cluster of three Space Shuttle main engines operates in parallel with the solid-rocket boosters during the initial ascent—through the first two minutes of flight until the boosters separate from the Shuttle and fall into the Atlantic Ocean. When the solid-rocket boosters separate at an altitude of approximately 44 kilometers (27 miles), Stage 2 beings. The Shuttle, with its main engines still burning, carries the external tank piggyback to near orbital velocity, approximately 113 kilometers (70 miles) above the Earth. There, 8.5 minutes into the mission, the now nearly empty external tank separates and falls in a preplanned trajectory into the Indian Ocean. By using this two-stage system, NASA scientists are able to make the upper stage much more efficient and able to reach much higher altitudes than they would have been able to do simply because the Shuttle no longer has to carry the spent solid-rocket boosters or the empty propellant tanks that make up the external tank.

In the following lab activity, you will use two inflated balloons to simulate a two-stage rocket launch such as is used by the Shuttle. Why balloons? A rocket in its simplest form is a chamber enclosing a gas under pressure. A small opening at one end of the chamber (the nozzle) allows the gas to escape, and in so doing, provides a thrust that propels the rocket in the opposite direction. There is a strong similarity between a balloon loosing air through its nozzle and this simple rocket. Air inside a balloon is compressed by the balloon's rubber walls. The air pushes back so that the inward- and outward-pressing forces are balanced. When the nozzle is released, air escapes and propels the balloon in a rocket flight. See Figure 1. The only significant difference between the balloon and the Space Shuttle's rockets is the way the pressurized gas is produced. With the Shuttle, the gas is produced by burning propellants that can be solid or liquid in form. With the balloon, the gas is produced by your blowing air into the balloon's nozzle.

LAB ACTIVITY SHEET 1

FIGURE 1



Equipment and Materials

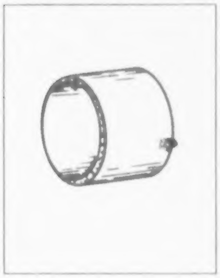
- Two long party balloons
- Tape measure
- Nylon-filament fishing line (any weight)
- Two milkshake-size plastic straws
- Styrofoam coffee cup
- Masking tape
- Scissors
- Classmate to assist you

Procedure

1. Measure lab-room distance from wall to wall
2. Cut length of fishing line to room measurement, allowing extra length to attach line to walls
3. Thread fishing line through the two plastic straws
4. Stretch fishing line taut across room and secure ends

   (NOTE: Make sure the line is just high enough for people to pass safely underneath.)
5. Move straws to one end of line
6. Cut coffee cup in half so that lip of cup forms a continuous ring (Figure 2)

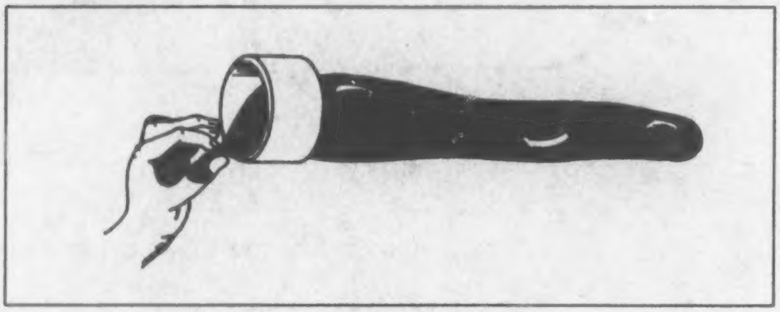
FIGURE 2



LAB ACTIVITY SHEET 1

7. Preinflate balloons to loosen them and then allow balloons to deflate
8. Prepare first balloon
    a. Inflate balloon about ¾ full of air
    b. Pinch nozzle closed with fingers and pull nozzle through coffee-cup ring (Figure 3)

FIGURE 3

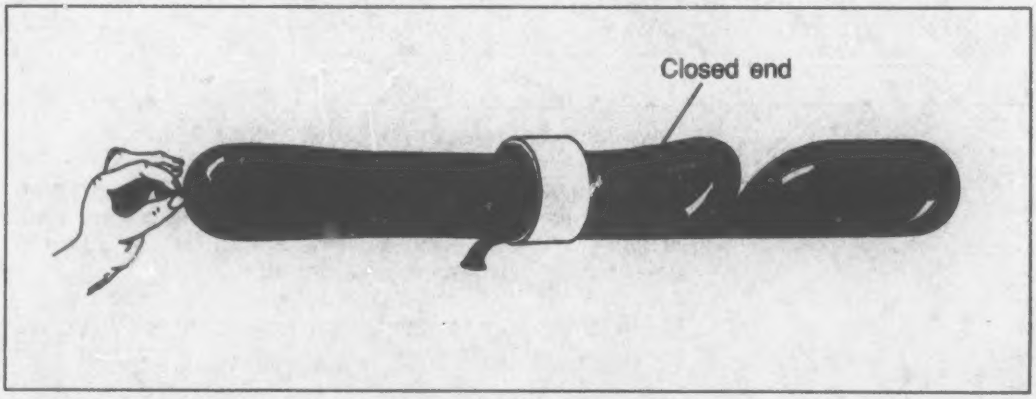


    c. Have assistant hold balloon in place while continuing to pinch nozzle closed

9. Prepare second balloon
    a. Place closed end of balloon inside coffee-cup ring (Figure 4) and begin to inflate balloon

    (NOTE: As the second balloon inflates, it will press against the nozzle of the first balloon and will hold it shut [see Figure 5], but it may take a bit of practice to achieve this.)

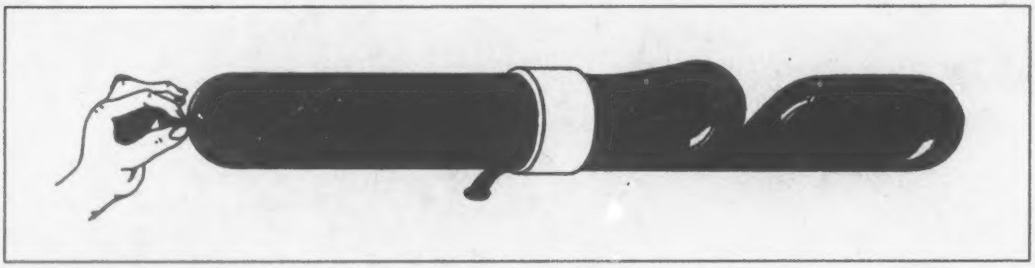
FIGURE 4



LAB ACTIVITY SHEET 1

b. When balloon is completely inflated and in position as shown in Figure 5, have assistant move to pinch nozzle of second balloon closed

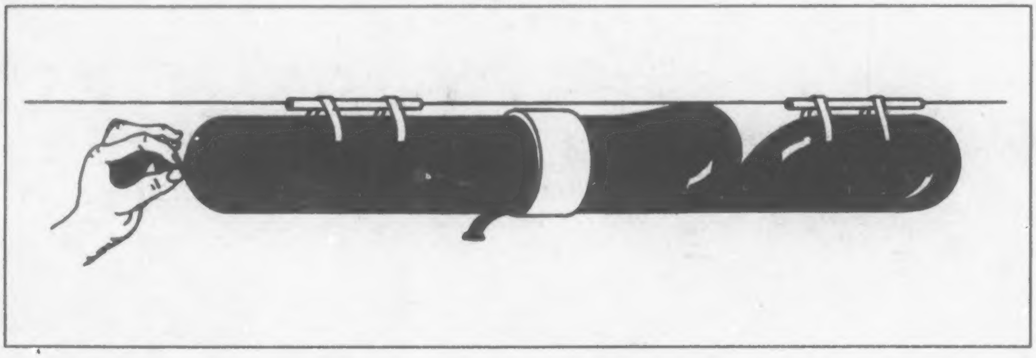
FIGURE 5



10. Tape balloons to straws as shown in Figure 6

(NOTE: The balloons should be pointed along the length of the fishing line.)

FIGURE 6



11. Have assistant release nozzle of second balloon

(NOTE: The escaping gas from the balloon will propel both balloons along the fishing line. When the balloon runs out of air, it will release the other balloon to continue the trip until that balloon also runs out of air.)

12. Clean lab area and properly store equipment and materials

Lab Activity Sheet 1 adapted with permission of the National Aeronautics and Space Administration from a preliminary draft of the teaching guide *Rockets* by Gregory L. Vogt, NASA Aerospace Education Services.

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

LAB ACTIVITY SHEET 2—CONSTRUCT A SOLID-PROPELLANT MODEL ROCKET

Introduction

In this lab activity, you will construct a solid-propellant model rocket from a rocket kit provided to you by your instructor. During the construction of your model, your instructor will require that you follow a strict safety code, never attempt to tamper with the design of the model-rocket kit you are given, and work only under his or her direct supervision. These precautions are necessary because there can be great danger associated with model rocketry. Even the most simple-looking model rockets are very complex in their design. Case-wall bursting strength, propellant packing density, nozzle design, and propellant chemistry are all design problems beyond the scope of you or any other amateur.

To prevent any injuries during the building of your rocket, the following safety rules will be followed in the classroom.

- A student will not experiment with rockets unless his or her activities are rigidly controlled and supervised by the instructor.
- Some propellant fuels are extremely hazardous, and untrained people sometimes attempt fuel combinations and firing methods that would be dangerous even if attempted by professional rocket experts.

  Under no circumstances, will a student build a rocket, mix rocket fuel, load a rocket, or attempt to launch it without supervision by the instructor. Nor will a student work alone with rocket fuel in a home or school laboratory.
- Because of the dangers associated with rocketry, each student will also follow the National Association of Rocketry's safety code in constructing and launching the model rocket he or she is to complete in this lab activity sheet. Study the model rocket safety code presented below.
- Read and sign the safety pledge presented in Student Supplement 4. If you are under the age of 18, your parent or legal guardian must also sign the safety pledge. You must turn in your completed safety pledge to your instructor for evaluation before you will be allowed to complete this lab activity.

LAB ACTIVITY SHEET 2

National Association of Rocketry's Solid-Propellant Model-Rocketry Safety Code*

1. **Construction**—My model rocket will be made of lightweight materials such as paper, wood, plastic, and rubber without any metal as structural parts.

2. **Engine**—I will use only the pre-loaded factory-made model rocket engine in the manner recommended by the manufacturer. I will not change in any way nor attempt to reload this engine.

3. **Recovery**—I will use a recovery system in my model rocket that will return it safely to the ground so that it may be flown again.

4. **Weight limits**—My model rocket will weigh no more than 453 grams (16 ounces) at liftoff, and the engine will contain no more than 133 grams (4 ounces) of propellant.

5. **Stability**—I will check the stability of my model rocket before its first flight, except when launching a model of already proven stability.

6. **Launching system**—The system I use to launch my model rocket must be remotely controlled and electrically operated, and will contain a switch that will return to OFF when released. I will remain at least 15 feet from any rocket that is being launched.

7. **Launch safety**—I will not let anyone approach a model rocket on a launcher until I have made sure that either the safety interlock key has been removed or the battery has been disconnected from my launcher.

8. **Flying conditions**—I will not launch my model rocket in high winds, near buildings, power lines, tall trees, low-flying aircraft, or under any conditions that might be dangerous to people or property.

9. **Launch area**—My model rocket will always be launched from a cleared area, free of any easy-to-burn materials, and I will only use nonflammable recovery wadding in my rocket.

10. **Jet deflector**—My launcher will have a jet-deflector device to prevent the engine exhaust from hitting the ground directly.

11. **Launch rod**—To prevent accidental eye injury, I will always place the launcher so the end of the rod is above eye level, or cap the end of the rod with my hand when approaching it. I will never place my head or body over the launching rod. When my launcher is not in use, I will always store it so that the launch rod is not in an upright position.

12. **Power lines**—I will never attempt to recover my rocket from a power line or other dangerous place.

---

*Safety Code reprinted with permission of the National Association of Rocketry.

LAB ACTIVITY SHEET 2

Solid-Propellant Model-Rocketry Safety Code (continued)

13. **Launch targets and angle**—I will not launch my rocket so that its flight path will carry it against a target on the ground, and I will never use an explosive warhead or a payload that is intended to be flammable. My launching device will always be pointed within 30 degrees of vertical.

14. **Pre-launch test**—When conducting research activities with unproven designs or methods, I will when possible determine their reliability through pre-launch tests. I will conduct launchings of unproven designs in complete isolation from persons not participating in the actual launchings.

Equipment and Materials

- NAR-approved solid-propellant model-rocket kit
- Scissors
- Pencil
- Ruler
- Sandpaper
- White glue
- Paint brush
- Modeling knife or utility blade
- Enamel spray paint (any color)
- Masking tape
- Sanding sealer

Procedure

(NOTE: Follow the instructions in the NAR-approved model-rocket kit to complete this activity. Read all the instructions and gather all needed equipment and materials before beginning work on your model. Test-fit all parts before applying any glue, and if any parts don't fit properly, sand as required for precision assembly.)

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

WRITTEN TEST

Name ______________________________ Score ______________

1. Match terms associated with propulsion systems to their correct definitions. Write the correct numbers on the blanks provided.

______ a. Agent used to support the combustion of a rocket propellant

______ b. Fuel plus an oxidizer that when ignited produces rapidly expanding gases that propel a rocket

1. Propellant
2. Oxidizer

2. State definitions of types of rocket propulsion systems. Write your definitions on the blanks provided.

a. Liquid-propellant ______________________________

____

____

____

b. Solid-propellant ______________________________

____

____

____

3. Match parts of a solid-propellant rocket engine to their correct definitions. Write the correct numbers on the blanks provided.

______ a. Gas-expansion device through which hot gases from combustion flow

______ b. Storage and combustion area for solid propellant

______ c. Storage and combustion area for agents used to ignite solid propellant

______ d. Solid fuel and an oxidizer compound

______ e. Narrow passageway where hot gases from combustion of solid propellant are channeled through case

1. Igniter
2. Case
3. Propellant
4. Core
5. Nozzle

WRITTEN TEST

4. Match parts of a liquid-propellant rocket engine to their correct definitions. Write the correct numbers on the blanks.

______a. Storage area for oxidizer

______b. Storage area for liquid fuel

______c. Gas-expansion device through which hot gases from combustion flow

______d. Chamber where propellant is burned

______e. Devices that mix liquid oxidizer and liquid fuel to create propellant and then force propellant into rocket's combustion chamber

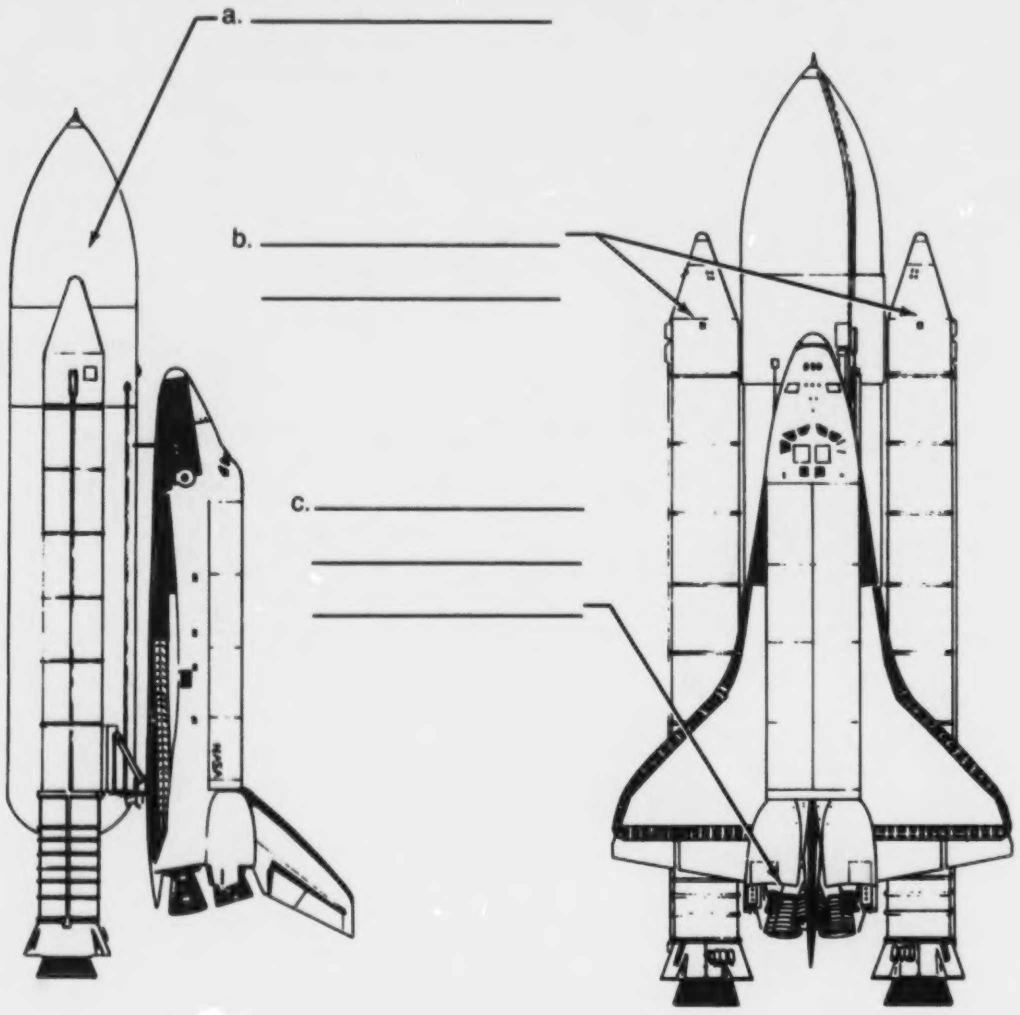
______f. Devices that force liquid fuel and liquid oxidizer from their storage tanks and into the injector areas of the rocket

1. Oxidizer tank
2. Fuel tank
3. Turbopumps
4. Injectors
5. Combustion chamber
6. Nozzle

5. Discuss the principle of rocket propulsion. Write your discussion on the blanks provided.

WRITTEN TEST

6. Label the major units of the Space Shuttle's propulsion system. Write your answers on the blanks provided in the illustration below.



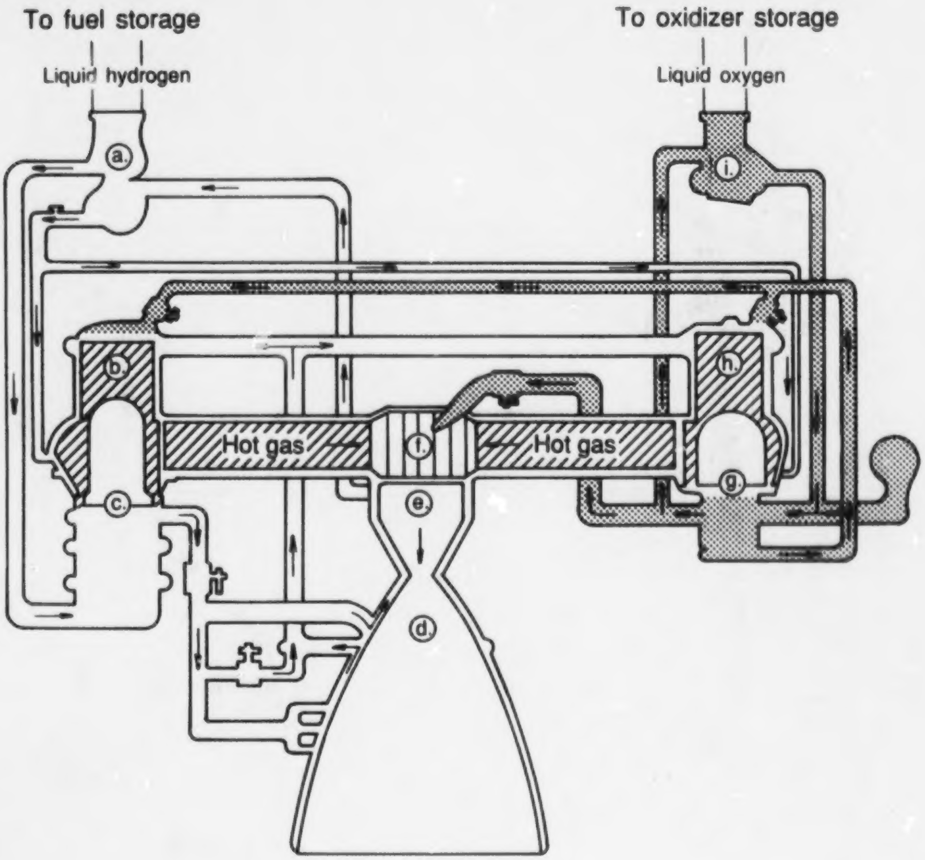
Side view

Front view

WRITTEN TEST

7. Identify the major components of the Space Shuttle's main engines. Write your answers on the blanks provided below the illustration.

Low-pressure fuel turbopump	**High-pressure fuel turbopump**
Main combustion chamber	**Nozzle**
Fuel preburner	**Main injector**
Low-pressure oxidizer turbopump	**High-pressure oxidizer turbopump**
Oxidizer preburner	


To fuel storage
Liquid hydrogen
To oxidizer storage
Liquid oxygen
a.
b.
c.
d.
e.
f.
g.
h.
i.
Hot gas
Hot gas

a. ______________________ f. ______________________

b. ______________________ g. ______________________

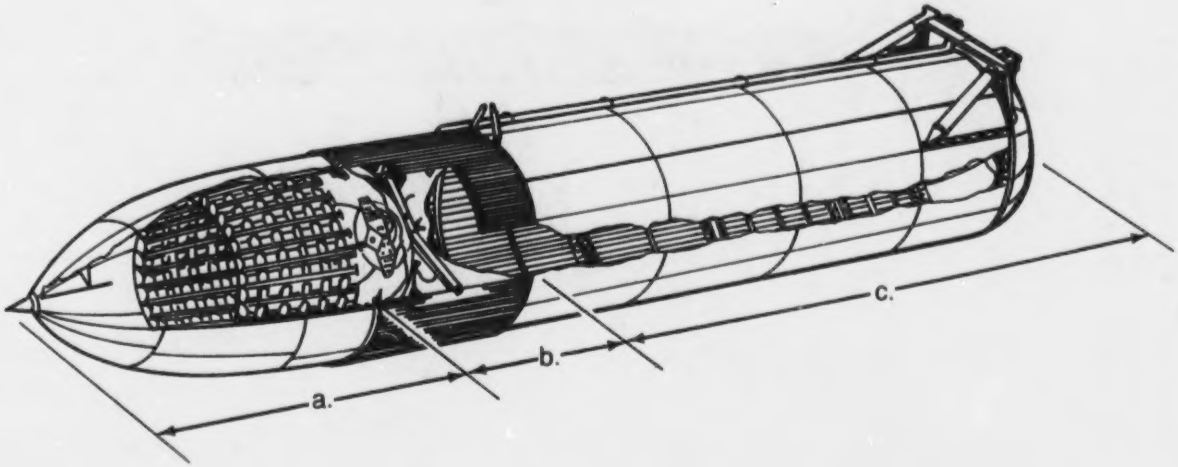
c. ______________________ h. ______________________

d. ______________________ i. ______________________

e. ______________________

WRITTEN TEST

8. Label the major components of the Space Shuttle's external tank. Write your answers on the blanks provided below the illustration.

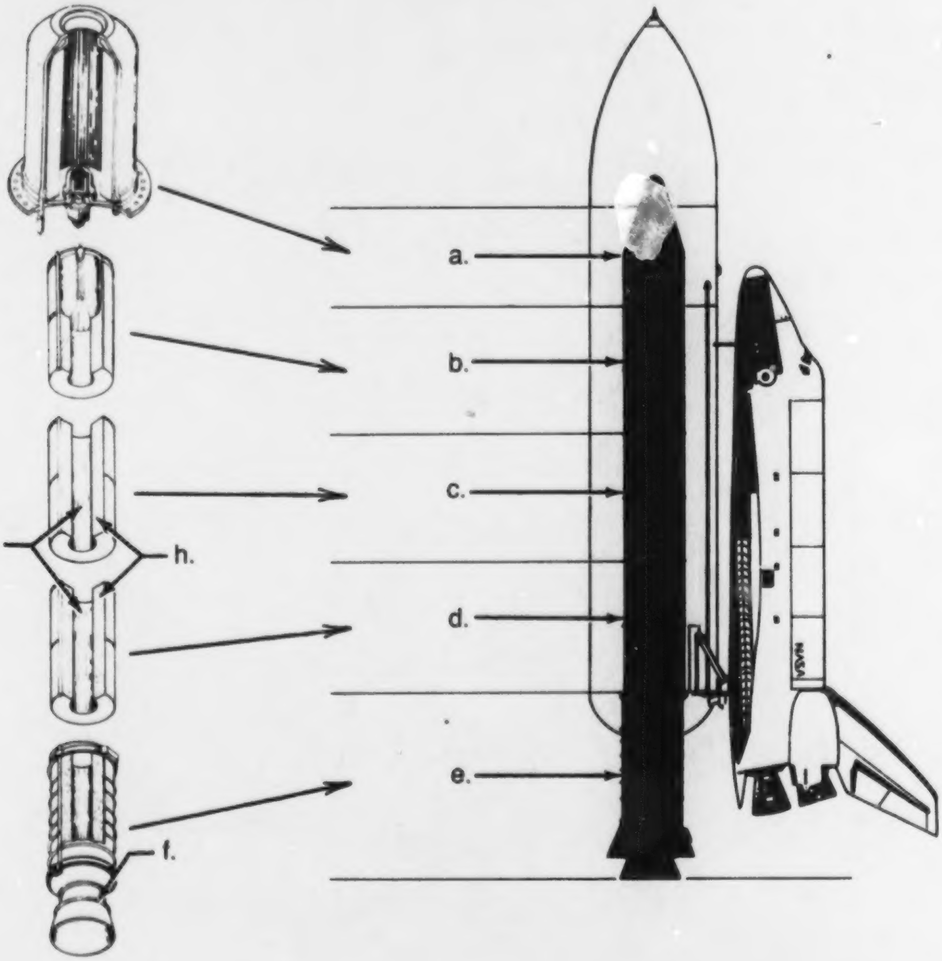


a. ______________ b. ______________ c. ______________

WRITTEN TEST

9. Identify the major components of the Space Shuttle's solid-rocket boosters. Write your answers on the blanks provided below the illustration.

Nozzle
Propellant
Core
Ignition system
Motor case: Forward segment
Motor case: Forward center segment
Motor case: Aft center segment
Motor case: Aft segment with nozzle



a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

h. ____________________

SPACE-SHUTTLE PROPULSION SYSTEMS
UNIT V

WRITTEN TEST ANSWERS

1. a. 2
   b. 1

2. a. Rocket type that uses a liquid or gas propellant in the propulsion system
   b. Rocket type that uses a solid-compound propellant in the propulsion system

3. a. 5
   b. 2
   c. 1
   d. 3
   e. 4

4. a. 1
   b. 2
   c. 6
   d. 5
   e. 4
   f. 3

5. Discussion should include the following

   a. Burning of rocket propellant within combustion chamber produces very hot high-pressure gases
   b. High chamber pressure produced by propellant combustion forces gases through engine nozzle
   c. The **action** of expelling gases in one direction causes a **reaction** that thrusts engine in opposite direction
   d. The mass and velocity of exhaust gases determine amount of force of resultant thrust

6. a. External tank (ET)
   b. Two solid-rocket boosters (SRBs)
   c. Space Shuttle's three main liquid-propellant rocket engines (SSMEs)

7. a. Low-pressure fuel turbopump
   b. Fuel preburner
   c. High-pressure fuel turbopump
   d. Nozzle
   e. Main combustion chamber
   f. Main injector
   g. High-pressure oxidizer turbopump
   h. Oxidizer preburner
   i. Low-pressure oxidizer turbopump

WRITTEN TEST ANSWERS

8. a. Liquid-oxygen tank
   b. Intertank
   c. Liquid-hydrogen tank

9. a. Ignition system
   b. Motor case: Forward segment
   c. Motor case: Forward center segment
   d. Motor case: Aft center segment
   e. Motor case: Aft segment with nozzle
   f. Nozzle
   g. Core
   h. Propellant

AEROSTATICS AND AERODYNAMICS
UNIT VI

UNIT OBJECTIVE

After completing this unit, the student should be able to define *aerostatics* and *aerodynamics*, state basic principles of aerostatics and aerodynamics, and apply these definitions and principles in building an aerostatic vehicle and an aerodynamic vehicle. The student will demonstrate these competencies by completing the lab activity sheets and the written test with a minimum score of 85 percent.

SPECIFIC OBJECTIVES

After completing this unit, the student should be able to

1. State definitions of terms associated with aerostatics and aerodynamics.
2. State the Buoyancy Principle.
3. State Bernoulli's Principle.
4. Match basic forces acting on an aerodyne in flight to their correct definitions.
5. State descriptions of the basic parts of a glider.
6. State definitions of the components of the cross-sectional shape of an aircraft's wing.
7. Define *dihedral angle*.
8. Build an aerostatic vehicle. (Lab Activity Sheet 1)
9. Build an aerodynamic vehicle. (Lab Activity Sheet 2)

AEROSTATICS AND AERODYNAMICS
UNIT VI

SUGGESTED ACTIVITIES

Preparation

- Review unit and plan presentation. Study the specific objectives to determine the order in which you will present the objectives.

  Review teaching suggestions given in the "Delivery and Application" section and plan classroom activities. Also note suggestions for supplemental materials.

  Plan presentation to take advantage of student learning styles and to accommodate special-needs students.

- Obtain films, videotapes, and other media to supplement instruction of this unit.

- Prepare classroom and lab. Put up posters, charts, and signs. Display articles related to the objectives of this unit.

- Carefully review Lab Activity Sheet 1, "Build an Aerostatic Vehicle" to determine the materials needed to complete this activity.

  Note that this activity will require the use of a large amount of tissuepaper. Tissuepaper can be found most anywhere in packs of ten 20″-by-28″ sheets. These packs come in many colors. Although this form of tissuepaper is readily available in many colors, it has one disadvantage—it must be joined to accommodate the 9-foot gore template. The joining of these sheets requires a great deal of effort.

  White tissuepaper is sold to jewelers in rolls 20 inches wide by 100 or more feet long. Using this form of tissuepaper takes less effort in actually preparing for the lab activity, but does take some lead time to have it available when you need it. If you decide to use the jewelers roll, order by contacting

  Crystal Tissue Company
  Middletown, OH 45042
  Phone (513) 423-0731.

  More permanent balloons may also be made using Mylar and tape; however, the cost of the activity would be greater.

  This activity also requires a wire hoop for each hot-air balloon to be made. The hoop needed for the activity is best made by cutting away the bent portions of two coat hangers, bending the remaining portions into a circular form, and then taping the ends of the wire in place.

SUGGESTED ACTIVITIES

You will also probably want to review the formula for figuring circumference, which students are required to do in this activity, and prepare visuals to review how this formula is used.

This activity also requires that you have some means of providing enough hot air to inflate the balloons once the students have them constructed. See Teacher Supplement 2 for instructions for constructing the propane burner to be used in inflating the hot-air balloons.

Decide too how students will perform this activity: singly or in groups. We recommend that the procedure be performed in groups of three or four students so that students will learn teamwork.

- Carefully review Lab Activity Sheet 2, "Build an Aerodynamic Vehicle." This activity requires the purchase of glider kits for each student. The glider constructed in the activity sheet is the Whitewings Racer 508 Sky Cub, which is available in a single-plane or six-plane kit from

AG Industries, Inc.
3832 148th Avenue, N.E.
Redmond, Washington 98052
Phone (206) 447-1824.

The procedures included in the lab activity are adapted from those included in the six-plane kit (order number AG 600).

Delivery and Application

Unit introduction

- Provide students with Teacher Supplement 1, "Short History of Flight." Read the history as an introduction to some of the principles and concepts that students will further explore in this unit. Use this supplement as a springboard for discussion of those principles and concepts.
- Provide students with objective sheet. Discuss unit and specific objectives.
- Provide students with information sheet. Discuss information sheet.

Objective 1 State definitions of terms associated with aerostatics and aerodynamics.

- Emphasize to students the literal meanings of the terms *aerostatics* and *aerodynamics*: *aerostatics* means "air at rest" and *aerodynamics* means "air in motion." Then relate the next two terms (aerostat and aerodyne) to the first two terms discussed.

SUGGESTED ACTIVITIES

- Point out to students the examples associated with the terms *aerostat* and *aerodyne*. Discuss the relationship of these examples to the terms defined: An aerostat—a hot-air balloon—can rise in still air (air at rest) and therefore the principles associated with lift in this vehicle come under the science of aerostatics. An aerodyne—airplane or glider—is heaver than air. The forces that create lift in an aircraft are created by the air moving around the aircraft's wings and therefore the principles associated with lift in this vehicle come under the science of aerodynamics.

Objective 2 State the Buoyancy Principle.

- Relate to students that the Buoyancy Principle is the principle used to describe the forces that create lift when an aerostat rises within a still mass of air—and this is the principle they will be applying in Lab Activity Sheet 1, "Build an Aerostatic Vehicle."
- Review the principle with the students and then read with students and discuss the introduction to Lab Activity Sheet 1, where the principle is further explored.
- Discuss with students techniques for enlarging the gore template in Student Supplement 1, figuring circumference of a circle, and creating the wire hoop that will be needed for this activity.
- Divide students into work groups, if you decide this activity should be performed by groups, and then discuss the steps in the procedure and answer any questions about it. Also explain to students the method you will use to inflate the balloon and any safety rules you may insist they follow in completing this process.
- Have students complete Lab Activity Sheet 1.

Objective 3 State Bernoulli's Principle.

- Relate to students that Bernoulli's Principle is the principle used to describe the forces that create lift as an airflow moves over the surface of an aerodyne's wing—and this is the principle they will be applying in Lab Activity Sheet 2, "Build an Aerodynamic Vehicle."

Objectives 4 through 7

- Follow Objective 3 with these objectives, which relate to students some basic concepts of how lift is created with an aerodyne: forces acting on an airplane in flight; basic parts of a glider; components of the cross-sectional shape of an aircraft's wing; dihedral angle. Discuss each of these objectives individually and then read with students and discuss the introduction to Lab Activity Sheet 2, where these concepts are further explored.

SUGGESTED ACTIVITIES

- Discuss with students the steps in the procedure outlined in the lab activity sheet and demonstrate steps as needed.
- Have students complete Lab Activity Sheet 2.

Evaluation

- Give written test.
- Compile written-test and lab-activity-sheet scores.
- Reteach and retest as required.

Suggested Resources

Resources used in developing unit

Print media

- National Aeronautics and Space Administration. *NASA, The First 25 Years 1958-1983: A Resource for Teachers.* Washington, D.C.: Government Printing Office, 1983.

  As the title suggests, this book was designed to be used as a curriculum resource for classroom teachers. The book was compiled on the 25th anniversary of NASA to provide an historical resource book to give teachers easy access to NASA activities since the agency was founded in 1958.

  The book begins with a prologue, a brief history of the National Advisory Committee for Aeronautics, NASA's predecessor, and then Chapter I introduces NASA—the agency, its physical plant, and its mission. Succeeding chapters are devoted to major NASA programs. Each chapter concludes with ideas for the classroom and space for notes and new information the user may wish to add. The epilogue offers some perspectives on the first 25 years and a glimpse of the future.

- Poff, Norman O. *Of Wings and Things.* Oklahoma State University, Stillwater, Oklahoma: NASA Educational Services, 1987.

  Of Wings and Things can be ordered at no charge from the following address:

  Of Wings and Things
  NASA/AESP
  300 North Cordell
  Dept. of Aviation and Space Education
  Oklahoma State University
  Stillwater, OK 74078-0422

SUGGESTED ACTIVITIES

This book contains various models, games, activities, and information originally designed as a workbook for instructors involved in a one- or two-day aeronautics workshop. For each activity only the most necessary instructions and important concepts are included. To incorporate the material into your curriculum, you must add any additional instructions needed to fit the level of students you teach.

Talay, Theodore A. *Introduction to the Aerodynamics of Flight*. Washington, D.C.: National Aeronautics and Space Administration, Scientific and Technical Information Office, 1975.

This book is the result of the author's teaching several semesters of an introductory course in aerodynamics to apprentices and technicians at the NASA Langley Research Center. In publishing this illustrated set of notes used in the classes, the author's purpose was to provide a text that would be more than a layman's treatment of the subject of aerodynamics but not the great detail used in a text for many college-level courses.

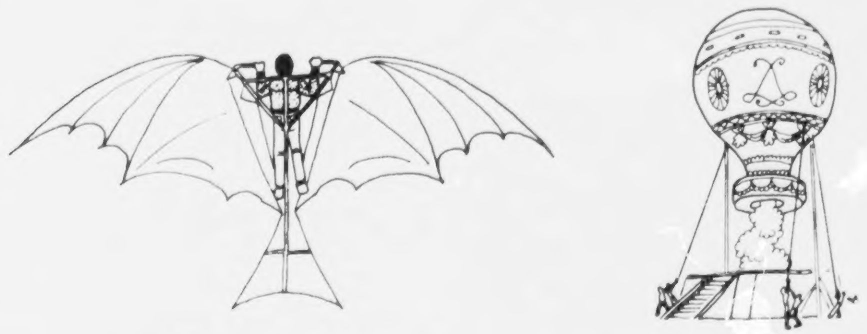
AEROSTATICS AND AERODYNAMICS
UNIT VI

TEACHER SUPPLEMENT 1—SHORT HISTORY OF FLIGHT

The development of the formal science of aerodynamics was the culmination of the observations and studies of many individuals that probably began with prehistoric human's watching birds fly through the air. Early humans, being unable to soar into the heavens themselves, attributed to their gods the ability to fly. Then, Greek philosophers began to question whether humans could fly. They asked: What is this substance called *air* and can a human fly in it? Aristotle conceived the notion that air had weight, and Archimedes formed a basic principle that described the forces of lift in lighter-than-air vehicles. Scientists like Galileo, Roger Bacon, and Pascal proved that air is a gas, air is compressible, and air pressure decreases with altitude.

Around 1500, one man—Leonardo da Vinci—foresaw the shape of things to come. Through his careful observations and studies of birds in flight came da Vinci's principles and designs that later were to influence many other designers. Da Vinci correctly concluded that the movement of the bird's wing relative to the air resulted in producing the lift necessary for the bird to be able to fly. As a result of da Vinci's studies, he designed several ornithopters—machines that were intended to copy the flapping action of a bird's wing. See Figure 1-a. Da Vinci believed a human's muscles could power his ornithopters, but he never built a full-scale ornithopter from his designs—his designs never left the drawing board.

FIGURE 1



(a) Da Vinci's ornithopter

(b) Montgolfier's balloon

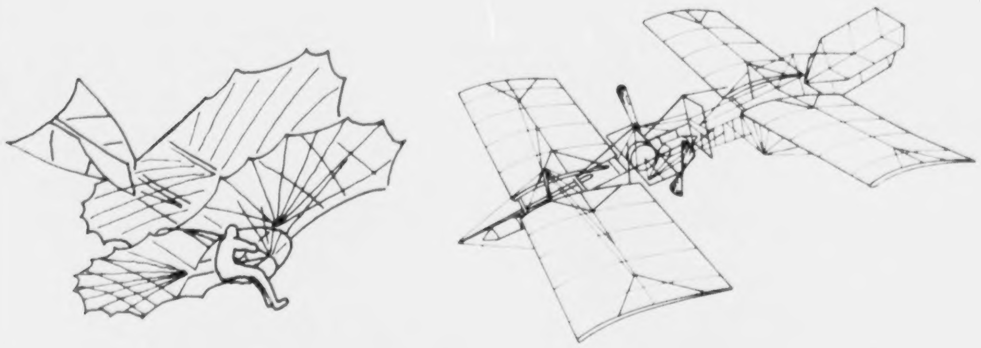
The first flying machine to carry a person did not imitate the flight of birds as da Vinci had studied. Instead, the design of the first flying machine was based on the lighter-than-air principle conceived by Archimedes. In 1783 the Montgolfier brothers of France, constructed a hot-air balloon (see Figure 1-b) that initiated the first ascent of a human into the atmosphere. Although ballooning thereafter became a popular pastime, balloons were at the mercy of the winds and could not fly where a pilot willed. Therefore, balloon designs gradually acquired small engines and steering devices, but they remained lighter-than-air (aerostat) vehicles. Heavier-than-air (aerodyne) flight was still years away.

TEACHER SUPPLEMENT 1

Sir George Cayley of England (1773-1857) is generally recognized as the father of modern aerodynamics. He understood the basic forces acting on a wing: he realized the importance of the wing's angle of attack and that a wing with curved surfaces would produce more lift than a wing with flat surfaces. He also understood that he could achieve stability in his designs through the use of the wing's dihedral and a tail unit. Cayley built and successfully flew several small-scale non-passenger-carrying gliders based on his new design principles. In 1853, it is believed, he built a full-size passenger-carrying glider that flew once with one of his servants as the passenger.

Toward the end of the nineteenth century, a German named Otto Lilienthal was successfully flying and piloting gliders of his design. He recorded over 2000 successful flights before crashing to his death in 1896. Figure 2-a shows one of Lilienthal's glider designs. Lilienthal proved the concept of heavier-than-air flight. Today, Lilienthal's glider designs would be called *hang-gliders*, and this design concept is enjoying a substantial comeback.

FIGURE 2



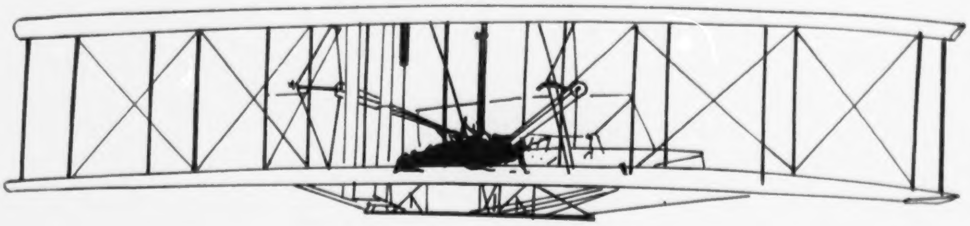
(a) Lilienthal's glider (1896) (b) Samuel Langley's "Aerodrome" (1903)

Although there are various claims as to who really flew the first powered flight, Americans are generally given the credit. At the Smithsonian Institution in Washington, D.C., Dr. Samuel Pierpont Langley designed small-scale steam-powered airplanes. His most successful model was a 5-meter-wing-span tandem biplane (see Figure 2-b), he called *the Aerodrome*. Fitted with a steam engine that drove two propellers, this small-scale Aerodrome flew over 1 kilometer in 1896. Then, backed by a grant from Congress, Langley built a full-scale version of the Aerodrome that he hoped would successfully carry a pilot. Unfortunately, launching-gear failure caused the Aerodrome to crash twice during October and December of 1903.

On December 17, 1903, at 10:35 a.m., near Kitty Hawk, North Carolina, the Wright brothers achieved success in a gasoline-engine-powered machine of their design (see Figure 3) when Orville Wright made the first powered and piloted flight of 120 feet in 12 seconds.

TEACHER SUPPLEMENT 1

FIGURE 3



Wright Flyer (1903)

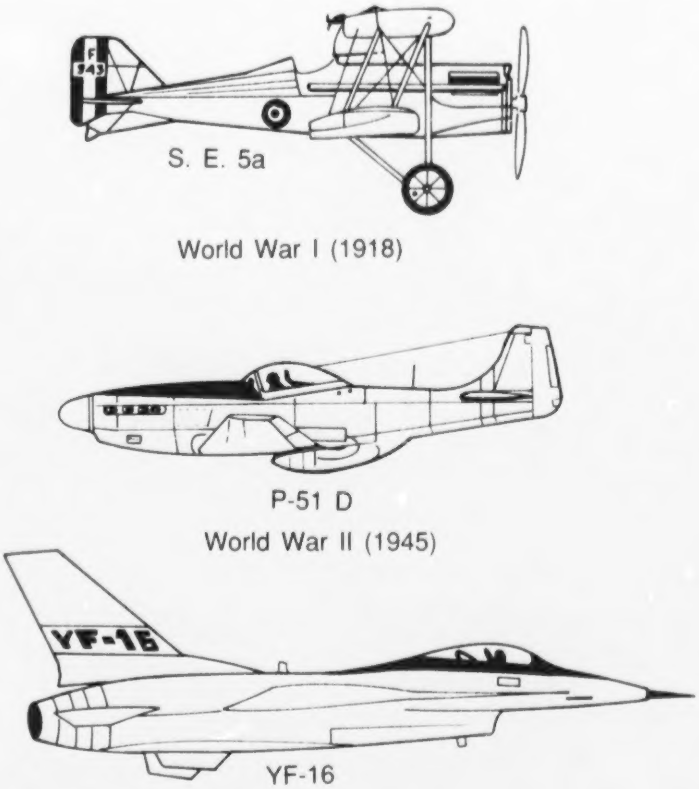
After the Wrights' invention became known, progress in aeronautics was rapid and continual with new flight records established regularly. During the first decade after the Wright brothers' flight, the Wrights sold their Military Flyer to the U.S. Army; in 1906 Europe saw its first powered flight; the English Channel was crossed; international meets took place on both sides of the Atlantic; the Wright Factory in Dayton produced aircraft manufactured to a standard design pattern. There was radio from plane to ground, a landing on the deck of a ship, and the first practical seaplane. The first U.S. transcontinental flight, which began on Long Island and ended in California, took 82 hours, 2 minutes flying time and 70 landings. The year 1912 brought the first parachute jump from an airplane and an aircraft speed record of 108.17 mph.

The first regularly scheduled airline in America began operation in 1914. Passenger and cargo potential were being recognized. Factories and flying schools were established. When World War I came, every major nation had aeronautical research facilities—except the United States.

The two world wars spurred advances in airplane design. See Figure 4. Aerial combat was commonplace by the end of World War I (1918), and at the end of World War II (1945) the Germans advanced concepts that pointed the way to future developments in aerodynamics. Soon swept-wing and jet-propulsion aircraft dominated both military and civilian sectors of aviation. Today, research is being pushed forward in the areas of transonic, supersonic, and hypersonic transports, lifting bodies, and the space shuttle.

TEACHER SUPPLEMENT 1

FIGURE 4



S. E. 5a

World War I (1918)

P-51 D

World War II (1945)

YF-16

(1974)

Teacher Supplement 1 adapted with permission from *Introduction to the Aerodynamics of Flight* by Theodore A. Talay, National Aeronautics and Space Administration, 1975. Figure 3 reprinted with permission from *NASA, The First 25 Years 1958-1983: A Resource for Teachers* by the National Aeronautics and Space Administration, 1983.

AEROSTATICS AND AERODYNAMICS
UNIT VI

TEACHER SUPPLEMENT 2—INSTRUCTIONS FOR CONSTRUCTING PROPANE-BURNER INFLATION DEVICE

In order for students to be able to complete Lab Activity Sheet 1, "Build an Aerostatic Vehicle," you will need to construct an apparatus as the heat source for the hot air to be used in inflating the hot-air balloons.

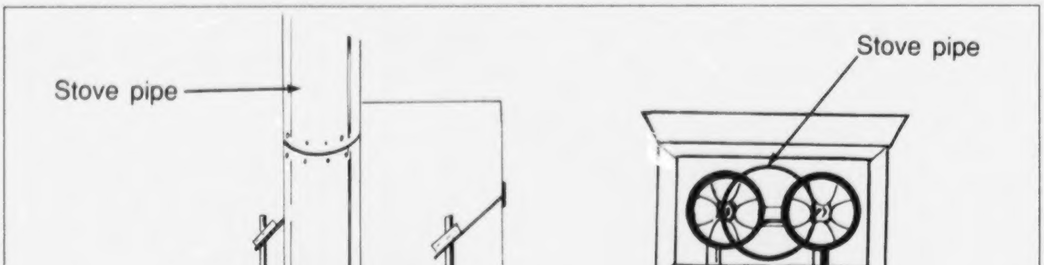
To construct the heat source, you will need to collect the following materials:

- Portable propane-burning camping stove, such as is produced by the Coleman Company
- Manufacturer's operating and safety instructions for the camping stove
- 3½- to 4-foot length of standard stove pipe
- Matches
- Propane for fuel

Follow the procedure and the illustrations in Figure 1 below to construct the heat source.

1. Follow manufacturer's instructions for assembling the stove, filling it with fuel, and igniting one burner.
2. Set burner control on the highest possible setting.
3. Place stove pipe over ignited burner and let stand in place for a few minutes.
4. Place balloon over stove pipe to fill balloon with hot air.

FIGURE 1



AEROSTATICS AND AERODYNAMICS
UNIT VI

INFORMATION SHEET

1. **Terms and definitions associated with aerostatics and aerodynamics**

   a. **Aerostatics**—Air at rest; science dealing with the equilibrium of gases and fluids and of solid bodies immersed in them

   b. **Aerodynamics**—Air in motion; science dealing with the behavior of moving air and the forces that it produces

   c. **Aerostat**—Lighter-than-air craft

   EXAMPLE: Hot-air balloon

   d. **Aerodyne**—Heavier-than-air craft

   EXAMPLES: Airplanes and gliders

2. **Buoyancy Principle**—The pressure in any fluid, liquid, or gas increases with the depth

   (NOTE: The Buoyancy Principle is used to describe the forces that create lift when an aerostat rises within a static mass of air.)

3. **Bernoulli's Principle**—With any airflow, as the speed of the air increases, pressure decreases

   (NOTE: Bernoulli's Principle is used to describe the forces that create lift as an airflow moves over the surfaces of an aerodyne's wing.)

4. **Basic forces acting on an aerodyne in flight and their definitions**

   (NOTE: For an aerodyne to maintain a straight and level flight path, the four basic forces listed below must be maintained in equal opposition: the lift must equal the weight, and the thrust must equal the drag. See Figure 1.)

   a. Lift—Upward force that causes craft to rise

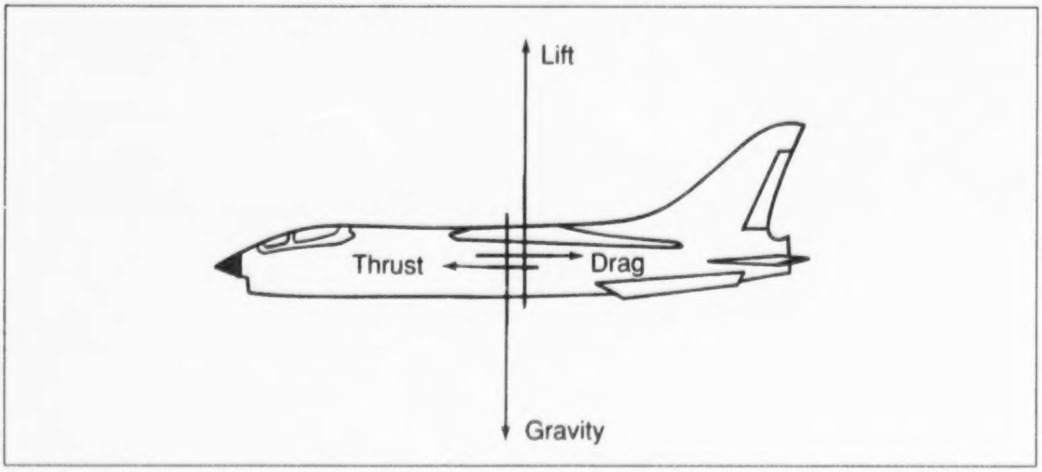
   b. Gravity—Downward force that pulls craft toward earth

   c. Thrust—Any force in the same direction as the forward movement of the craft

   d. Drag—Any force in the opposite direction of the forward movement of the craft

INFORMATION SHEET

FIGURE 1


Lift
Thrust
Drag
Gravity

Reprinted with permission from *Introduction to the Aerodynamics of Flight* by Theodore A. Talay, National Aeronautics and Space Administration, 1975.

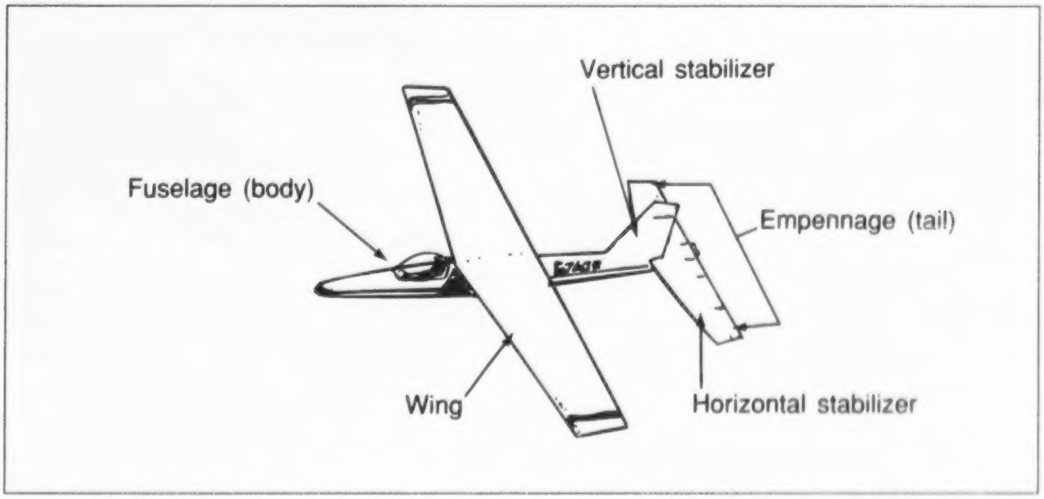
5. **Basic parts of a glider and their descriptions** (Figure 2)

   a. Fuselage (body)—Basic structure to which other large components of the aircraft are attached

   b. Wing—Structure that provides principle lifting force of aircraft

   c. Empennage (tail)—Structure consisting of the vertical stabilizer and the horizontal stabilizer; provides directional and longitudinal stability

FIGURE 2

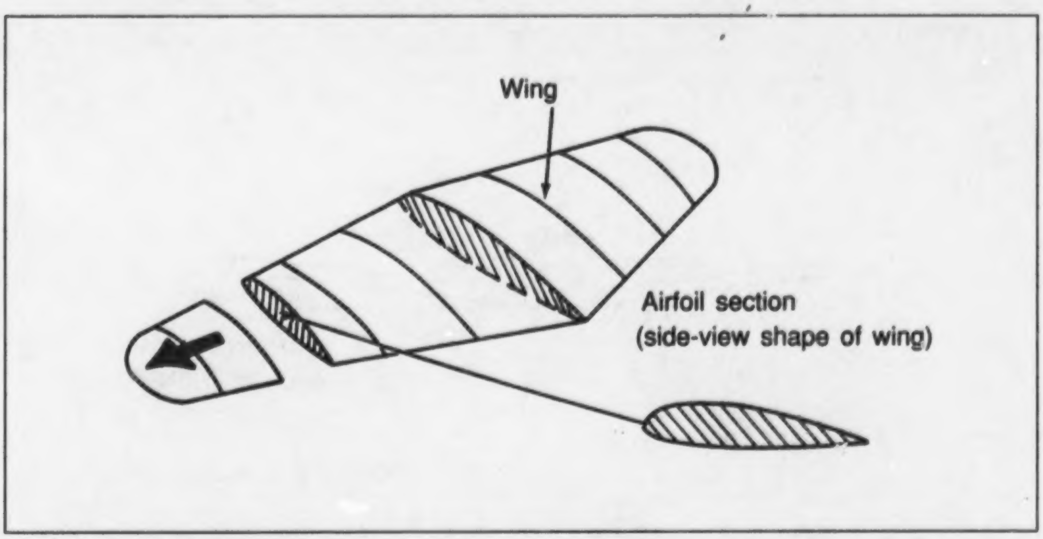

Vertical stabilizer
Fuselage (body)
Empennage (tail)
Wing
Horizontal stabilizer

INFORMATION SHEET

6. **Definitions of the components of the [illegible]-sectional shape of an aircraft's wing**

   a. Airfoil—Cross-sectional shape of the wing (Figure 3)

FIGURE 3


Wing
Airfoil section
(side-view shape of wing)

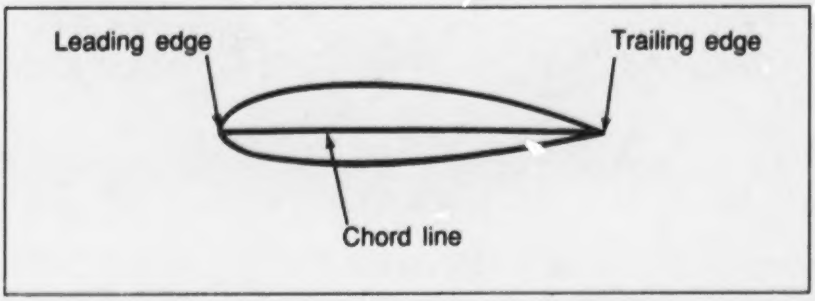
Reprinted with permission from *Introduction to the Aerodynamics of Flight* by Theodore A. Talay, National Aeronautics and Space Administration, 1975.

   b. Leading edge—Rounded front portion of wing that first meets oncoming airflow (see Figure 4)

   c. Trailing edge—Sharp rear portion of wing where the upper and lower airflow meet after passing over wing's upper and lower surfaces (see Figure 4)

   d. Chord line—Imaginary straight line drawn from leading edge to trailing edge (Figure 4)

FIGURE 4

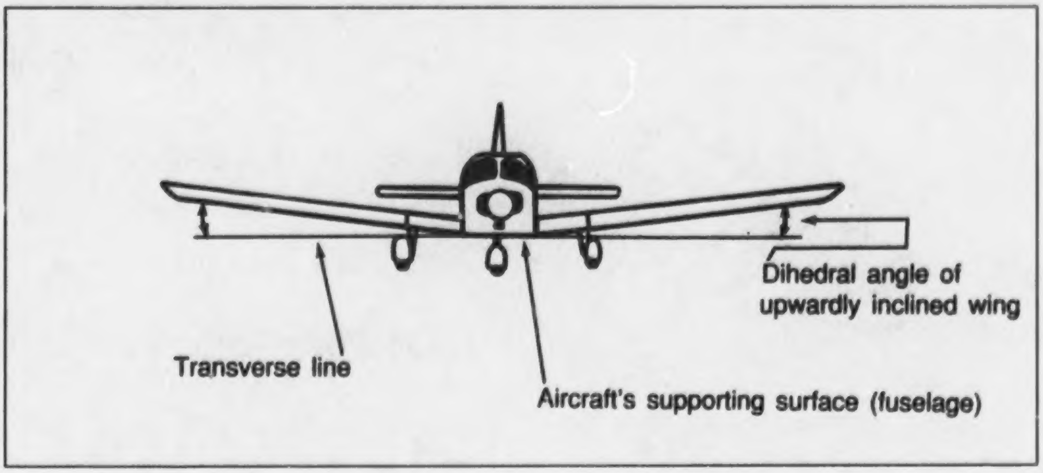

Leading edge
Trailing edge
Chord line

INFORMATION SHEET

7. **Definition of *dihedral angle*** (see Figure 5)—Angle between either an upwardly inclined wing or a downwardly inclined wing and a transverse line from aircraft's supporting surface

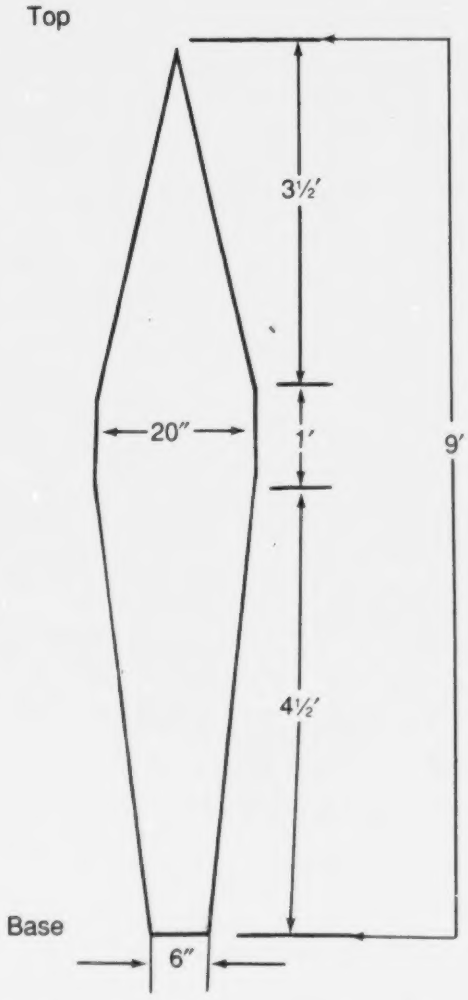
(NOTE: The dihedral angle of an aircraft's wing is a stabilizing device used when the craft's wings are tilted up or down during flight.)

FIGURE 5


Dihedral angle of upwardly inclined wing
Transverse line
Aircraft's supporting surface (fuselage)

AEROSTATICS AND AERODYNAMICS
UNIT VI

STUDENT SUPPLEMENT 1—GORE PATTERN FOR TISSUEPAPER HOT-AIR BALLOON



Reprinted with permission from *Of Wings and Things* by Norman O. Poff, NASA Educational Services, Oklahoma State University, Stillwater, Oklahoma, 1987.

AERОSTATICS AND AERODYNAMICS
UNIT VI

LAB ACTIVITY SHEET 1—BUILD AN AEROSTATIC VEHICLE

Introduction

Lighter-than-air craft (aerostat)

The first successful aircraft of any kind was a hot-air balloon constructed in 1783 by Joseph and Etienne Montgolfier. The Montgolfier brothers did not actually realize what caused their balloon to ascend. They thought at first that burning wood released some unknown gas that mysteriously caused objects to rise. However, the true principle of lighter-than-air flight soon became known.

The principle explaining how a balloon works is called the Buoyancy Principle: **The pressure in any fluid, liquid, or gas increases with the depth.**

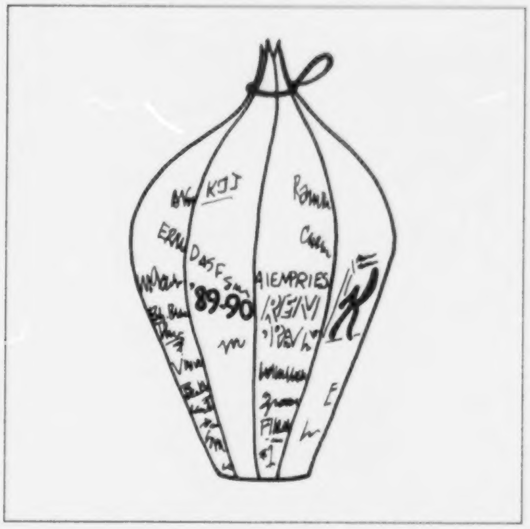
The atmosphere surrounding the earth is nothing more than an ocean of air (a gas) held in place by gravity. If you stand on the earth's surface, you are at the bottom of this ocean of air (at its greatest depth) and the air surrounding you is under the greatest pressure, which causes the air to compress to its greatest density or greatest weight per cubic foot. If you go up in altitude, or rise in this ocean of air, you are essentially decreasing the depth of the air above you. The air surrounding you at that greater altitude is under less pressure and is therefore less dense or weighs less per cubic foot.

A balloon has a gas trapped inside its airbag, which is also called its *envelope*. The gas trapped inside the envelope is of a lesser density (or lesser weight per cubic foot) than the air surrounding the balloon. This imbalance of the densities of the gases inside and outside the balloon causes an imbalance in pressure, which causes an upward force to be exerted on the balloon. This upward force, called *lift*, causes the balloon to rise when released. The balloon will then rise in the atmosphere until it eventually reaches a point where the density of the air outside the balloon is the same as the density of the gas inside the balloon's envelope. At this point, the pressures causing lift—the upward force—are in balance and the balloon will no longer rise.

Balloons are referred to as *aerostatic vehicles*, which means that they will lift in a static air mass—an air mass that is not moving. It is not a difficult task to build a hot-air balloon with which to demonstrate the Buoyancy Principle. Follow the steps in the following procedure to build a tissuepaper hot-air balloon—your own aerostatic vehicle. See Figure 1.

LAB ACTIVITY SHEET 1

FIGURE 1



Equipment and Materials

- Student Supplement 1, "Gore Pattern for Tissuepaper Hot-Air Balloon"
- Measuring tools and pencil
- Butcher paper
- Posterboard or other lightweight but stiff material to be used in making gore template
- Tissuepaper supplied by instructor
- Scissors
- Permanent felt-tip markers
- Glue stick
- Two all-wire coat hangers
- Pliers to be used in shaping coat hangers into a hoop
- String
- Small hand-held hairdryer
- Fish line (approximately 10 feet)

LAB ACTIVITY SHEET 1

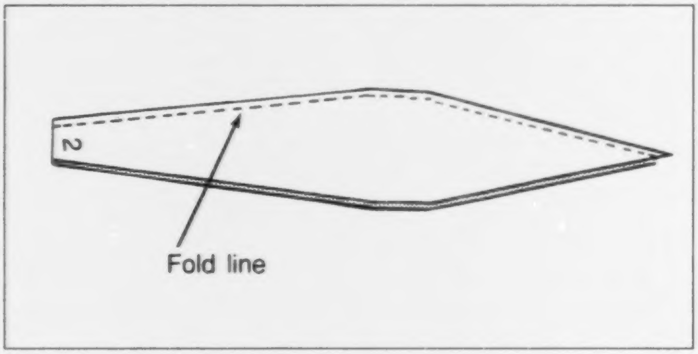
Procedure

1. Make gore template
    a. Using measuring tools and pencil, create full-size gore pattern on butcher paper
    b. Trace full-size gore pattern onto posterboard or other stiff material
    c. Cut out posterboard gore template
2. Make 10 tissuepaper gores
    a. Stack 10 pieces of tissuepaper on top of each other
    b. Place gore template on top of tissuepaper and cut around template to complete gores
3. Separate gores and number them from 1 to 10, writing a small number at the base of each gore; decorate each gore surface

(NOTE: Use permanent felt-tip markers and/or designs cut from colored tissuepaper to decorate the gores. Do **not** use water-soluble markers; they will eat through the tissuepaper.)

4. Combine gores
    a. Place gore 1 on flat surface
    b. Place gore 2 on top of gore 1 and then slide gore 2 about ½ inch back from edge of gore 1 as shown in Figure 2

FIGURE 2



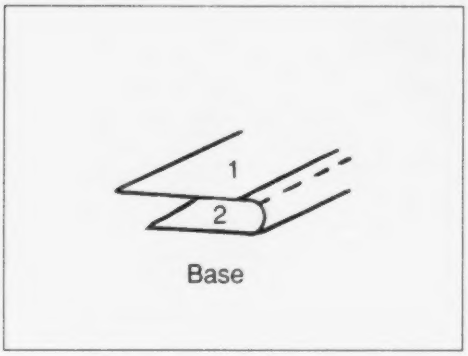
    c. Create fold line by carefully folding ½-inch margin of gore 2 over gore 1

LAB ACTIVITY SHEET 1

d. Place glue on fold and bond fold of gore 2 to gore 1, creating combined unit-a

e. Fold combined unit-a as shown in Figure 3

FIGURE 3



f. Place gore 3 on flat surface

g. Place gore 2 of combined unit-a on top of gore 3

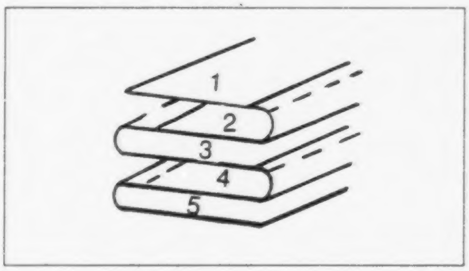
h. Slide combined unit-a back about ½ inch from the edge of gore 3

i. Carefully fold ½-inch margin of gore 2 over gore 3

j. Place glue on fold and bond fold of gore 2 to gore 3, creating combined unit-a/b

k. Continue folding and gluing gores (gore 4 over gore 3, gore 5 over gore 4, etc.) until all free edges have been bonded except one edge on gore 1 and one edge on gore 10 (Figure 4)

FIGURE 4



l. Glue free edge of gore 1 to free edge of gore 10

LAB ACTIVITY SHEET 1

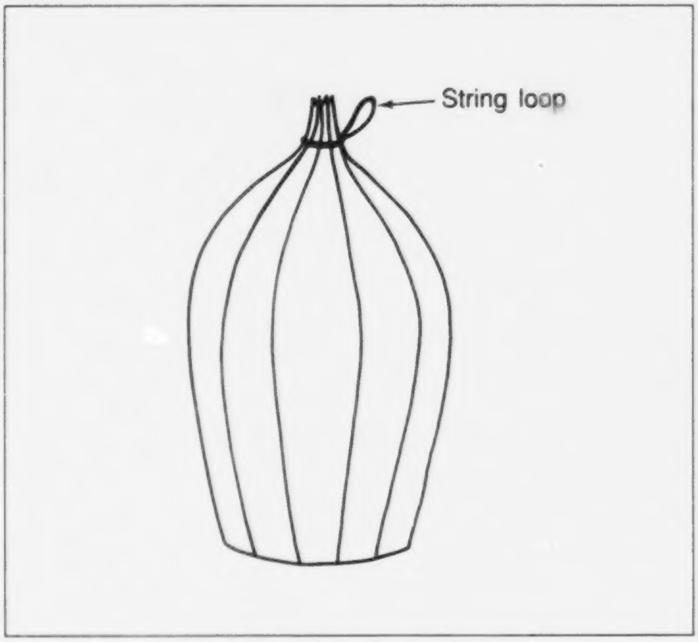
5. Finish top of combined gores

   a. Measure and cut two pieces of string about 12 inches long

   b. Measure down about 6 inches from top of combined gores, grasp and encircle tissuepaper with fist at 6-inch mark; tie top closed with one piece of string

   c. Create loop with second piece of string and attach to top of combined gores as shown in Figure 5

FIGURE 5



6. Finish base of combined gores

   a. Measure diameter of base and calculate circumference

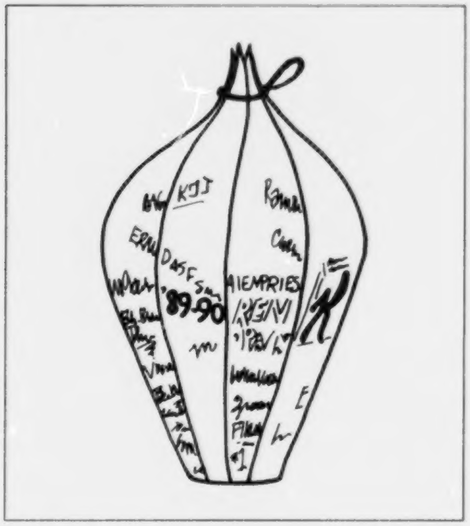
   b. Form hoop from two all-wire coat hangers, bending and shaping wires to calculated circumference

   c. Place hoop approximately 2 inches inside base

   d. Fold bottom edge of tissuepaper over inserted hoop and glue folded edge to inside of base—you have constructed the envelope of your hot-air balloon (see Figure 6)

LAB ACTIVITY SHEET 1

FIGURE 6



7. Test balloon envelope for holes and tears
    a. Hang balloon from string loop attached to top
    b. Insert hairdryer into hoop at base of balloon and move airstream around inside surface of balloon while checking balloon surface for unglued seams, tears, and holes
8. Repair holes and tears with small bits of tissuepaper and glue *if* necessary
9. Reglue seams *if* necessary
10. Attach one end of fish line to base of balloon to be used as a tether during the inflation process
11. Have instructor inspect your work and guide you through the process of inflating the balloon over propane burner
12. When balloon is properly inflated and becomes buoyant, let it go
13. Clean work area and return equipment and materials to proper storage

Lab Activity Sheet 1 adapted with permission from *Of Wings and Things* by Norman O. Poff, NASA Educational Services, Oklahoma State University, Stillwater, Oklahoma, 1987.

AEROSTATICS AND AERODYNAMICS
UNIT VI

LAB ACTIVITY SHEET 2—BUILD AN AERODYNAMIC VEHICLE

Introduction

Heavier-than-air craft (aerodyne)

Both gliders and airplanes are heavier-than-air machines. They cannot produce lift in a static air mass like balloons. To produce lift, they depend instead on the forces created by moving air. The study of the behavior of moving air and the forces that it produces is called *aerodynamics*, meaning, literally, "air in motion."

Understanding the principles of aerodynamics is a more complicated task than understanding the principles of aerostatics. However, you can understand these principles by taking them a stage at a time. The first stage in this process is understanding the opposing forces that act on an aircraft in flight: lift and gravity, thrust and drag.

As it was with balloons, *lift* is the upward force that causes an aircraft to rise. *Gravity*, or the weight of the aircraft, is the downward force that pulls the aircraft toward earth.

Thrust is any force that causes the aircraft to move forward in the same direction that the aircraft is moving through the air. *Drag* is any backward force in the opposite direction of the forward movement of the aircraft.

Lift

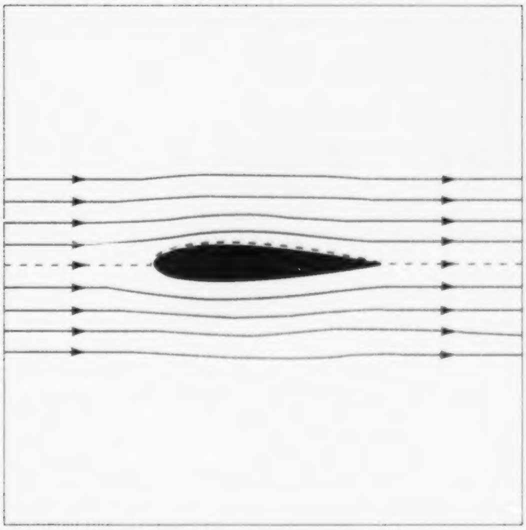
In order to rise into the air, an aircraft must be able to create enough lift to overcome the downward force of gravity. With airplanes and gliders, the wing is the device used to create the upward force that overcomes the downward force of gravity.

Lift on an aircraft can be explained by using Bernoulli's Principle: **With any airflow, as the speed of the air increases pressure decreases.**

To visualize this principle, think of a wing as being in a wind tunnel, as shown in Figure 1. Ahead of the wing, the airflow has a uniform speed. When the flow of air in the wind tunnel reaches the wing, the airflow is forced to divide. One part of the airflow flows over the upper surface of the wing and the other part flows over the lower surface of the wing.

LAB ACTIVITY SHEET 2

FIGURE 1



With a wing of the typical shape shown in Figure 1, the upper surface of the wing is thicker than the lower surface. Since the wing's upper surface is thicker, the speed of the air flowing over the upper surface is greater than the speed of the air flowing over the lower surface. The difference in the speeds of the two airflows causes a greater pressure to be exerted on the lower part of the wing than on the upper. This difference in pressure causes the upward force needed to create lift.

There are two major ways to increase lift of an aircraft: (1) by increasing thrust—the forward speed of the aircraft—and (2) by increasing the angle of attack of the wing.

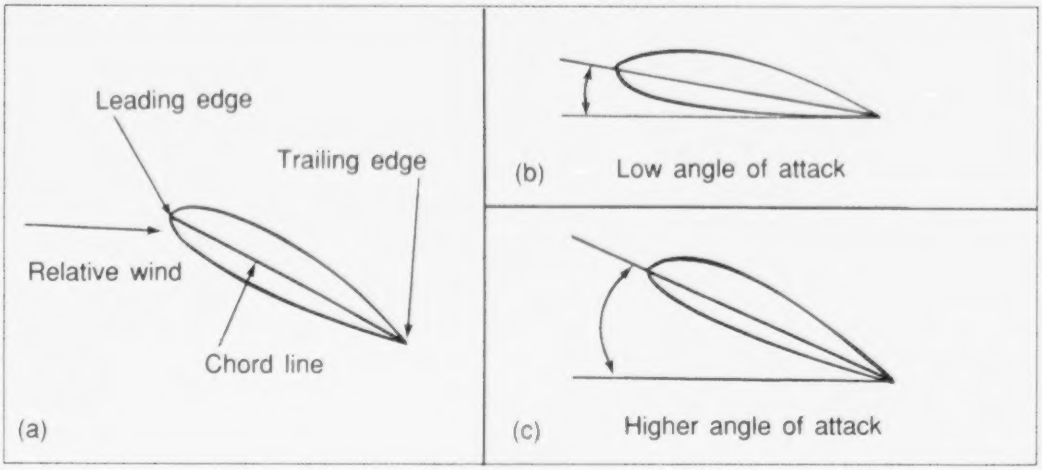
Again by applying Bernoulli's Principle and visualizing the wing in a wind tunnel, you can understand how an increased thrust increases the speed of the airflow passing over the wing therefore creating more lift: the greater the forward speed of the aircraft, the greater the difference between the two pressures exerted on the wing surfaces, the greater the lift created.

Angle of attack

Visualizing and understanding how the wing's angle of attack affects lift is stage 2 in learning about lift. To understand *angle of attack*, you will need to review the definitions of the parts of an aircraft's wing, which you learned in the information sheet, as well as the new terms mentioned below. Consult Figure 2 to help you visualize the following definitions.

LAB ACTIVITY SHEET 2

FIGURE 2



- The **relative wind** is the term used in naming the direction of the airflow parallel and opposite to the flight path of the aircraft.
- The **leading edge** of the wing is the rounded front portion of the wing that first meets the oncoming airflow.
- The **trailing edge** is the sharp rear portion of the wing where the upper and lower airflow meet after passing over the wing's upper and lower surfaces.
- The **chord line** is an imaginary straight line drawn from the leading edge to the trailing edge. The chord line is used to define the angle of attack of the wing.
- The **angle of attack** is the angle formed between the chord line and the direction of the relative wind.
- A **low angle of attack** means that the angle formed between the chord line and the direction of the relative wind is small. See Figure 2-b.
- A **higher angle of attack** means that the angle formed between the chord line and the direction of the relative wind is larger. See Figure 2-c.

As the angle of attack increases, the flow of air no longer divides at the tip of the leading edge. It divides at a point farther down on the upper surface of the wing. This increases the *effective* upper surface area and decreases the *effective* lower surface area of the wing.

LAB ACTIVITY SHEET 2

Again by using Bernoulli's principle, you can understand how greater lift is created with a greater angle of attack: the greater effective upper surface area increases the speed of the air flowing over the upper surface. The reduced effective surface area of the lower surface reduces the speed of the airflow over the lower surface. The combination of these two factors decreases the pressure on the upper surface of the wing, increases the pressure on the lower surface of the wing, and creates a greater lift.

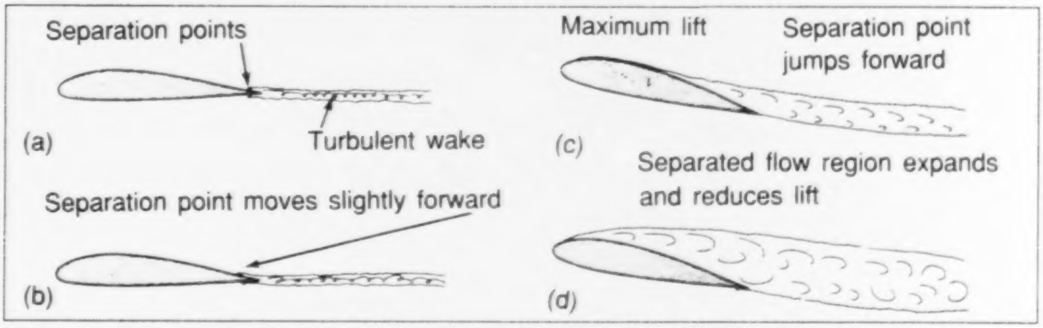
Stall

It would seem to follow that the greater the angle of attack, the greater the lift produced. That assumption is true to a degree; however, there is a limit. *Stall* is the term used to describe the condition created by increasing the angle of attack past a certain critical angle.

As the angle of attack increases, the air near the trailing edge of the wing starts to detach and separate from the upper surface of the wing. See Figure 3. This separation creates an area of turbulent air, called *burble*, near the trailing edge of the wing.

As the angle of attack continues to increase, the area of turbulent air moves rapidly forward on the upper portion of the wing. If the angle of attack is increased enough, the turbulent air covering the upper surface of the wing drastically decreases the wing's ability to produce lift. At the critical angle where lift decreases, stall occurs.

FIGURE 3


Separation points
(a)
Turbulent wake
Separation point moves slightly forward
(b)
Maximum lift
Separation point jumps forward
(c)
Separated flow region expands and reduces lift
(d)

Reprinted with permission from *Introduction to the Aerodynamics of Flight* by Theodore A. Talay, National Aeronautics and Space Administration, 1975.

Equipment and Materials

- Six-plane Whitewing balsa/fiber model glider kit

  (NOTE: The six-lane kit includes paper patterns, balsa fuselage, hook, and rubber band and rod [used for making rubber band catapult]. However Whitewing kits can also be purchased in individual packets.)

LAB ACTIVITY SHEET 2

- Desk or other flat work surface
- Newspaper or other large sheets of scrap paper
- Scissors
- X-acto knife
- Ruler
- Glue

  (NOTE: A clear, fast-drying glue is best. Dupont's Duco Cement, Allen Products Corporation's Seal All, or Titebond are examples of suitable glues.)

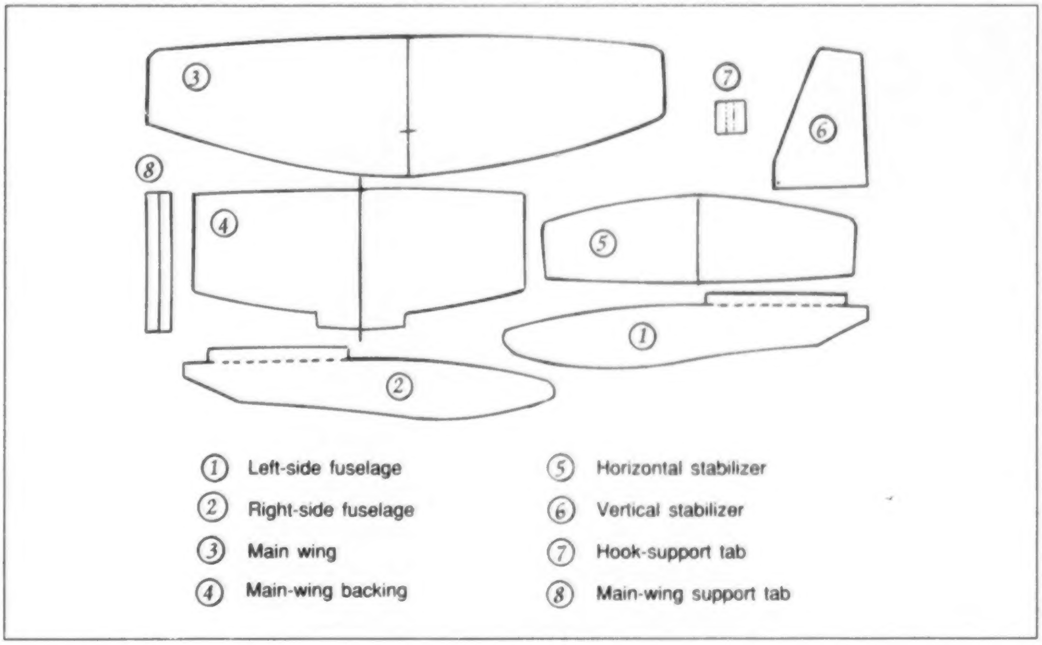
- T-pins or glass-bead pins

Procedure

(NOTE: When the right side [or left side] of the glider is mentioned, that means the right-hand side [or the left-hand side] of an imaginary pilot sitting in the cockpit.)

1. Locate paper pattern for Racer 508 Sky Cub (Figure 4)

FIGURE 4


③
⑦
⑥
⑧
④
⑤
①
②
① Left-side fuselage
② Right-side fuselage
③ Main wing
④ Main-wing backing
⑤ Horizontal stabilizer
⑥ Vertical stabilizer
⑦ Hook-support tab
⑧ Main-wing support tab

2. Plan cutting pattern for rough-cutting glider pattern pieces; consider the following

   — Plan cutting pattern that will leave at least a ⅛-inch margin around main-wing backing—piece 4; note extension lines on pattern piece (see Figure 4)

LAB ACTIVITY SHEET 2

— Plan cutting pattern so that you do not cut into adjacent pieces

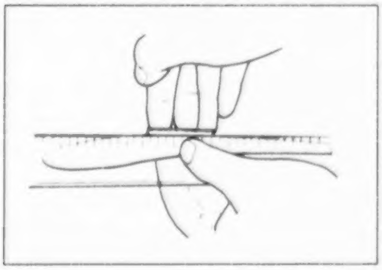
3. Using scissors, rough-cut around each pattern piece
4. Set piece for main-wing backing aside; it will **not** be trimmed at this time
5. Trim remaining rough-cut pieces to size by cutting precisely on solid lines on outside edges of each pattern piece

   (**CAUTION:** Do **not** cut on dashed lines; these are fold lines. Do **not** cut on interior lines with arrowheads; these are center lines also used for folding.)
6. Bend tabs on right- and left-side fuselage pieces—pieces 1 and 2
   a. Place fuselage piece with front surface up on work surface

      (NOTE: The front surface of the pattern piece is the printed side of the piece.)

   b. Place sharp edge of ruler on dashed line on fuselage piece
   c. Create neatly folded tab by bending tab over ruler edge (Figure 5)

FIGURE 5

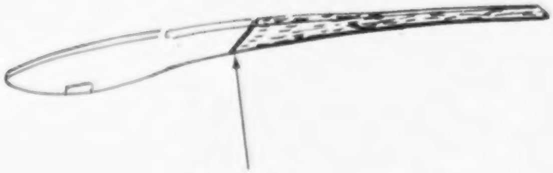


7. Spread scrap paper over work surface to protect it from glue
8. Assemble fuselage
   a. Locate balsa fuselage A and right and left fuselage pieces
   b. Test-fit fuselage pieces by aligning nose end of fuselage pieces with nose of balsa fuselage

LAB ACTIVITY SHEET 2

c. Mark line on each side of balsa fuselage where edge of paper fuselage piece rests on balsa fuselage (Figure 6)

FIGURE 6



d. Spread glue evenly over back surface of right and left paper fuselage pieces (see Figure 7-a) and then quickly glue paper fuselage pieces to balsa fuselage as they were test-fit in step b above (see Figure 7-b)

(**CAUTION:** The back surface of the piece is the bottom area and is not printed. Apply the glue evenly to this surface and use a sufficient amount. *If* you apply the glue unevenly, the plane will not be sturdy. *If* you do not apply enough glue, the glider pieces will not be firmly bonded, resulting in weak construction and poor flying performance.)

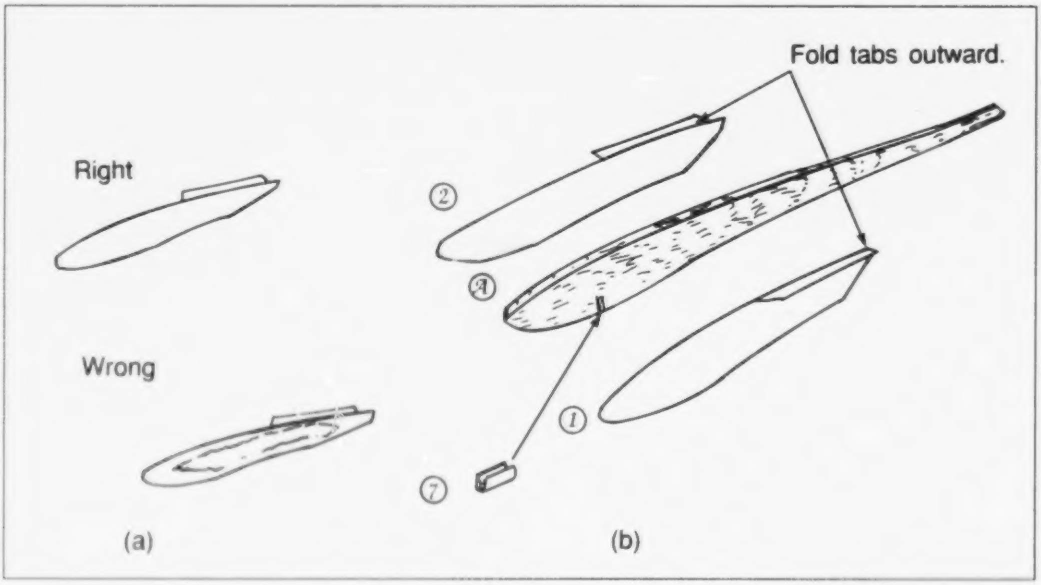
e. Place assembled fuselage inside a folded piece of scrap paper and press out excess glue with your fingers

f. Remove assembled fuselage from folded paper and set assembly aside for at least five or six hours to allow glue to dry thoroughly

g. After fuselage assembly has dried thoroughly, insert hook into balsa fuselage as shown in Figure 7-b

LAB ACTIVITY SHEET 2

FIGURE 7



h. Locate hook-support tab—pattern piece 7

i. Place pattern piece on work surface with pattern piece's front surface facing up

j. Fold pattern piece on dashed lines to create U-shape as shown in Figure 7-b

k. Apply glue to inside surfaces of U and glue pattern piece in place over hook as shown in Figure 7-b

l. Set fuselage assembly aside and allow glue on hook-support to dry thoroughly

9. Assemble wing

   a. Locate rough-cut main-wing backing—piece 4—and main wing—piece 3

   b. Place main-wing backing on work surface with front surface of pattern piece facing up (see Figure 8)

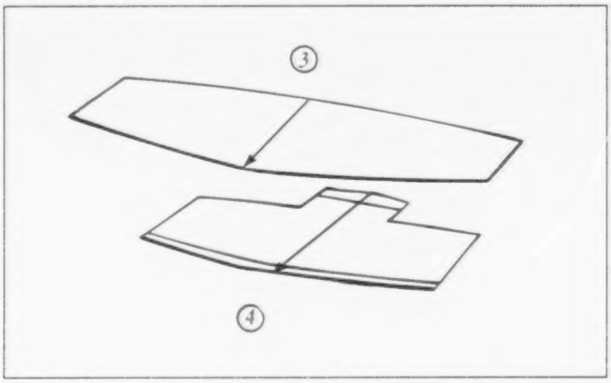
      (NOTE: The front surface of the pattern is the printed side.)

   c. Coat front surface of main-wing backing with glue

LAB ACTIVITY SHEET 2

d. Apply main-wing backing to back surface of main wing, aligning center lines as shown in Figure 8

FIGURE 8



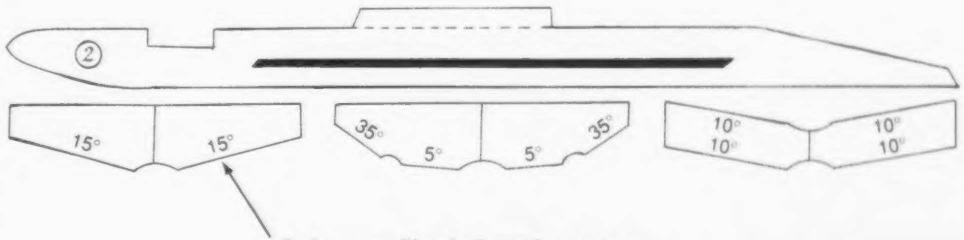
e. Set assembled wing aside and allow glue to dry for at least five or six hours

10. Create wing dihedral angle

a. Locate 15-degree dihedral-angle gauge included in kit

(NOTE: In the six-plane Whitewings kit, the angle gauge is found on the Jet Liner pattern; see Figure 9.)

FIGURE 9



15-degree dihedral-angle gauge

b. Rough-cut and then trim exterior lines of angle-gauge piece

LAB ACTIVITY SHEET 2

c. After wing assembly has dried thoroughly, place front surface of main wing face down on flat surface to expose protruding edge of main-wing backing

d. Carefully trim protruding edge of main-wing backing so that its edge is aligned with the outside edge of main wing

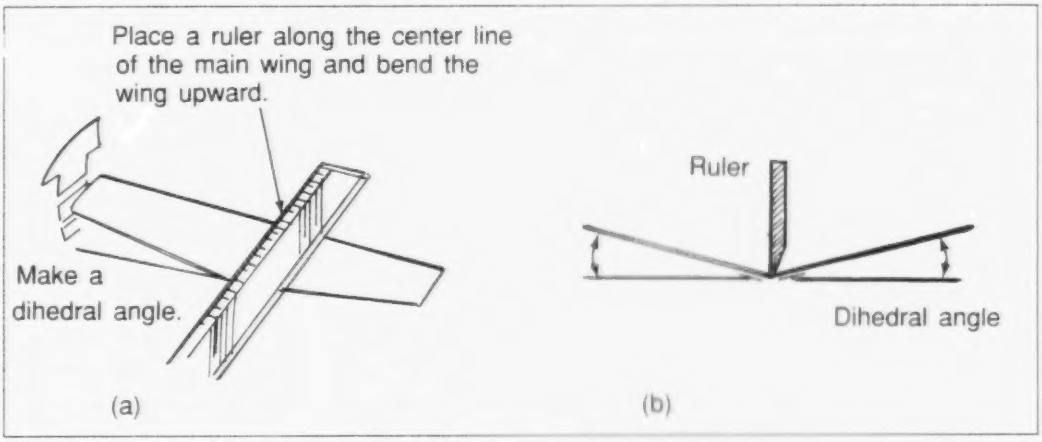
(**CAUTION:** Take care **not** to cut main wing.)

e. Turn wing assembly over (with front surface of main wing piece facing up) and place assembly on work surface

f. Have classmate hold angle gauge near one wing tip of wing assembly; place flat surface of angle gauge on work surface

g. Place ruler along center line of main wing piece, and using angle gauge as guide, bend wing slightly upward to create 15-degree dihedral angle (Figure 10)

FIGURE 10


Place a ruler along the center line of the main wing and bend the wing upward.
Make a dihedral angle.
(a)
Ruler
Dihedral angle
(b)

h. Have classmate hold angle gauge near second wing tip

i. Place ruler along center line of main wing piece, and using angle gauge as guide, bend wing slightly upward to create 15-degree dihedral angle

11. Attach horizontal stabilizer to balsa fuselage

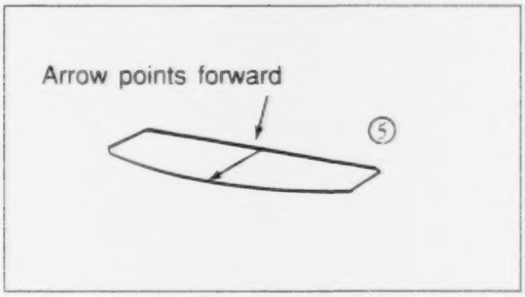
a. Locate horizontal stabilizer—piece 5

LAB ACTIVITY SHEET 2

b. Test-fit horizontal stabilizer on balsa fuselage

(1) Turn horizontal stabilizer so that its center-line arrow points forward to fuselage nose; place center line on stabilizer on center of balsa fuselage (see Figure 11)

FIGURE 11



(2) Align flat back end of stabilizer with rear edge of balsa fuselage

(3) Mark line on balsa fuselage at point where arrow on stabilizer center line rests on fuselage

c. Apply glue to balsa fuselage from its rear edge to mark on fuselage; quickly align stabilizer on balsa fuselage as it was test-fit above

12. Attach vertical stabilizer to balsa fuselage

a. Locate vertical stabilizer—piece 6

b. Test-fit vertical stabilizer on fuselage

(1) Turn stabilizer so that dot on pattern piece faces toward fuselage nose (see Figure 12-a)

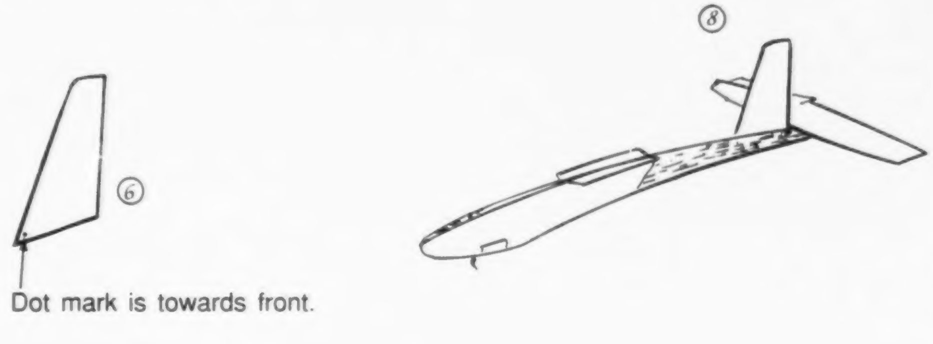
(2) Place stabilizer to right side of the top surface of the fuselage and with rear edge of vertical stabilizer touching front edge of horizontal stabilizer (see Figure 12-b)

(3) Mark line on balsa fuselage where front edge of stabilizer rests on fuselage

c. Apply glue to balsa fuselage and quickly align stabilizer as it was test-fit in step b above (see Figure 12-b)

LAB ACTIVITY SHEET 2

FIGURE 12



(a) (b)

13. Attach wing assembly to fuselage

    a. Locate wing assembly

    b. Test-fit wing assembly

        (1) Turn wing assembly so that arrow on center line points forward to nose of fuselage

        (2) Align edges of wing assembly with supporting tabs on right and left fuselage pieces

        (3) Center wing-assembly center line on top surface of balsa fuselage

        (4) Mark lines on balsa fuselage where front and rear edges of wing assembly rest on balsa fuselage

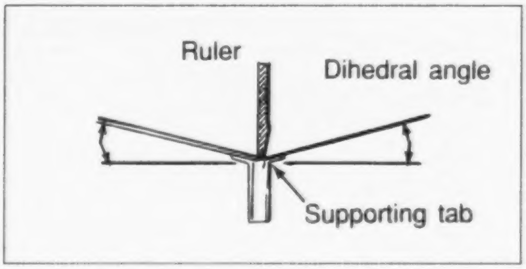
    c. Apply glue to top surface of supporting tabs and between marks on balsa fuselage

    d. Place wing assembly on balsa fuselage and supporting tabs as test-fit above

    e. Press down firmly on center line of wing assembly with sharp edge of ruler while pressing up from underside of supporting tabs (see Figure 13)

LAB ACTIVITY SHEET 2

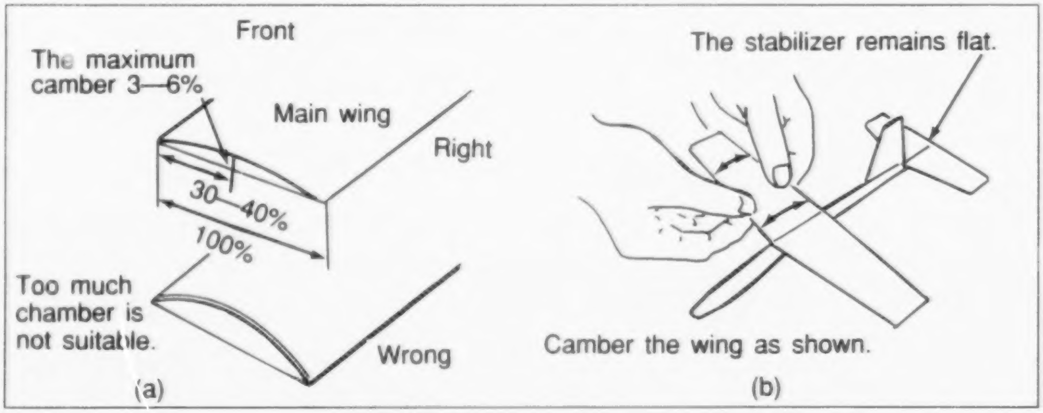
FIGURE 13


Ruler
Dihedral angle
Supporting tab

- f. Locate main-wing support tab—piece 8
- g. Place support tab with front surface facing up on work surface
- h. Place sharp edge of ruler on center line and fold each tab up slightly along center to form V
- i. Place glue along bottom surface of V
- j. Glue main-wing support tab to center line of wing assembly
- k. Place T-pins or glass-bead pins through support-tab center line and into balsa fuselage to anchor wing assembly
- l. Set glider aside to dry for three to four hours

14. When glider is dry, camber the wings slightly by bending wing assembly as shown in Figure 14-a and -b

FIGURE 14


Front
The maximum camber 3—6%
Main wing
Right
30—40%
100%
Too much chamber is not suitable.
Wrong
(a)
The stabilizer remains flat.
Camber the wing as shown.
(b)

LAB ACTIVITY SHEET 2

15. Inspect glider

    (NOTE: One of the secrets of flying a paper glider is to inspect the glider closely to detect any warps, bends, or twists.)

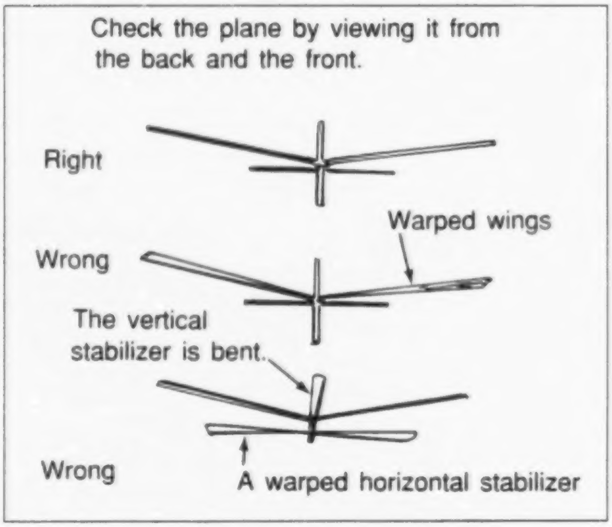
    a. Inspect glider from the front and from the rear; consider the following:

       — Are both right and left wings straight, perfectly matched, and inclined at the same angle?

       — Is the horizontal stabilizer warped or bent? (see Figure 15)

       — Is the vertical stabilizer warped or bent? (Figure 15)

FIGURE 15


Check the plane by viewing it from the back and the front.
Right
Warped wings
Wrong
The vertical stabilizer is bent.
Wrong
A warped horizontal stabilizer

    b. Straighten bent or warped pieces *if* necessary

16. Clean work surface and put away equipment and materials

Procedure in Lab Activity Sheet 2 adapted with permission from *Whitewings Assembly Instructions* booklet, AG Industries, Seattle, Washington, copyright 1982.

AEROSTATICS AND AERODYNAMICS
UNIT VI

WRITTEN TEST

Name ______________________________ Score ______________

1. State the definitions of the following terms associated with aerostatics and aerodynamics. Write your answers on the blanks provided with each term.

    a. Aerostatics ____

    ____

    ____

    ____

    b. Aerodynamics ____

    ____

    ____

    ____

    c. Aerostat ____

    ____

    d. Aerodyne ____

    ____

2. State the Buoyancy Principle. Write your answer on the blanks provided below.

    Buoyancy Principle ____

    ____

    ____

3. State Bernoulli's Principle. Write your answer on the blanks provided below.

    Bernoulli's Principle ____

    ____

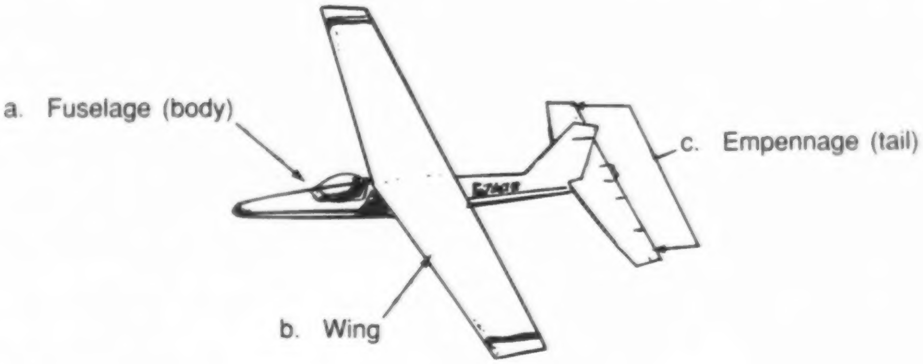
    ____

WRITTEN TEST

4. Match basic forces acting on an aerodyne in flight to their correct definitions. Write the correct numbers on the blanks provided.

_____a.	Any force in the opposite direction of the forward movement of the craft	1. Lift
		2. Gravity
_____b.	Downward force that pulls craft toward earth	3. Thrust
_____c.	Any force in the same direction as the forward movement of the craft	4. Drag
_____d.	Upward force that causes craft to rise	

5. State descriptions of the basic parts of the glider in the illustration below. Write your answers on the blanks provided.



a. Description ____

____

____

____

b. Description ____

____

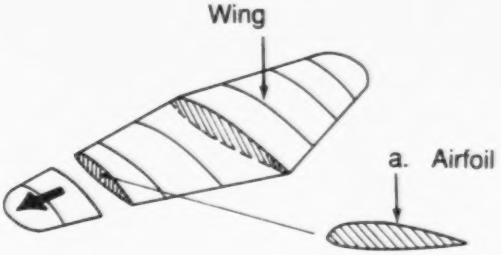
____

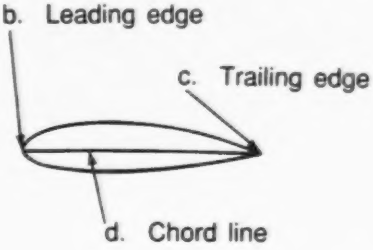
____

WRITTEN TEST

c. Description

6. State definitions of the components of the cross-sectional shape of the aircraft's wing shown in the illustrations below. Write your answers on the blanks provided.


Wing
a. Airfoil


b. Leading edge
c. Trailing edge
d. Chord line

a. Definition

b. Definition

c. Definition

d. Definition

WRITTEN TEST

7. Define *dihedral angle*. Write your answer on the blanks provided below.

Dihedral angle ____

____

____

AEROSTATICS AND AERODYNAMICS
UNIT VI

WRITTEN TEST ANSWERS

a. Air at rest; science dealing with the equilibrium of gases and fluids and of solid bodies immersed in them
b. Air in motion; science dealing with the behavior of moving air and the forces that it produces
c. Lighter-than-air craft
d. Heavier-than-air craft

2. The pressure in any fluid, liquid, or gas increases with the depth

3. With any airflow, as the speed of the air increases, pressure decreases

4. a. 4 c. 3
b. 2 d. 1

5. a. Basic structure to which other large components of the aircraft are attached
b. Structure that provides principle lifting force of aircraft
c. Structure consisting of the vertical stabilizer and the horizontal stabilizer; provides directional and longitudinal stability

6. a. Cross-sectional shape of the wing
b. Rounded front portion of wing that first meets oncoming airflow
c. Sharp rear portion of wing where upper and lower airflow meet after passing over wing's upper and lower surfaces
d. Imaginary straight line drawn from leading edge to trailing edge

7. Angle between either an upwardly inclined wing or a downwardly inclined wing and a transverse line from aircraft's supporting surface